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# Transactions of The Institution of Mining Engineers

Edited by the Secretary

VOL. XXIII.

1901-1902.

[*Frontispiece, Vol. xxiii.*]

GEORGE ARTHUR MITCHELL.

PRESIDENT OF HE INSTITUTION OF MINING ENGINEERS, 1895-1896.

# TRANSACTIONS

OF

# THE INSTITUTION

OF

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Mr. EDWARD LINDLEY, Eastwood, Nottingham.
Mr. HENRY LOUIS, 11, Windsor Terrace, Newcastle-upon-Tyne.
Mr. JOHN HERMAN MERIVALE, Togston Hall, Acklington, Northumberland.
Mr. M. H. MILLS, Sherwood Hall, Mansfield.
Mr. T. W. H. MITCHELL, Mining Offices, Regent Street, Barnsley.
Mr. JOHN MORISON, Cramlington House, Northumberland.
Mr. DAVID M. MOWAT, Summerlee Iron Works, Coatbridge, N.B.
Mr. JOHN NEVIN, Littlemoor House, Mirfield.
Mr. HENRY PALMER, Medomsley, R.S.O., Co. Durham.
Mr. J. M. RONALDSON, H.M. Inspector of Mines, 44, Athole Gardens, Glasgow.
Mr. FRANK ROBERT SIMPSON, Hedgefield House, Blaydon-upon-Tyne.
Mr. ALEXANDER SMITH, 3, Newhall Street, Birmingham.
*Mr. JOHN STRICK, Bar Hill, Madeley, Staffordshire.
Mr. EDWARD B. WAIN, Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.

## Auditors.

Messrs. JOHN G. BENSON AND SONS, Newcastle-upon-Tyne.

## Treasurers.

Messrs. LAMBTON AND COMPANY, The Bank, Newcastle-upon-Tyne.

## Secretary.

Mr. MARTIN WALTON BROWN, Neville Hall, Newcastle-upon-Tyne.

# THE INSTITUTION OF MINING ENGINEERS.

FOUNDED JULY 1ST, 1889.

## BYE-LAWS

*As revised at Council Meeting held on May 29th, 1902.*

### I.—CONSTITUTION.

1.—The Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

(*a*) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.

(*b*) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.

(*c*) The publication of original communications, discussions, and other papers connected with the objects of the Institution.

(*d*) The purchase and disposal of real and personal property for such objects.

(*e*) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

### II.—MEMBERSHIP.

6.—The original adherents or founders are as follows:—

(*a*) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.

(*b*) Midland Institute of Mining, Civil and Mechanical Engineers, Barnsley.

(*c*) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.

(*d*) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—"The members shall consist of Ordinary Members, Associate Members and Honorary Members, with Associates and Students:—

(*a*) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.

(*b*) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.

(*c*) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.

(*d*) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.

(*e*) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

## III.—Subscriptions.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

## IV.—Election of Officers and Council.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one Vice-President per two hundred Ordinary Members or Associate Members thereof; and of a President elected by and from the Council at their first meeting in each year; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer, shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

## V.—Duties of Officers and Council.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda-paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

## VI.—General Meetings.

38.—An ordinary general meeting shall be held in February, May and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

## VII.—Publications.

41.—The publications may comprise:—

(*a*) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.
(*b*) Papers on the management of industrial operations.
(*c*) Abstracts of foreign papers upon similar subjects.
(*d*) An abstract of the patents relating to mining and metallurgy, etc.
(*e*) Notes of questions of law concerning mines, manufactures, railways. etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes, shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of The Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council:—to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution, as a body, is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution or of the Federated Institutes.

## VIII.—Medals and other Rewards.

55.—The Council, if they think fit in any year, may award a sum not exceeding sixty pounds, in the form of medals or other rewards, to the author or authors of papers published in the *Transactions*.

## IX.—Property.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses :—

(*a*) The interest of its accumulated capital fund;

(*b*) The annual subscriptions ; and

(*c*) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

## X.—Alteration of Bye-Laws.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

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# TRANSACTIONS

OF

# THE INSTITUTION

OF

# MINING ENGINEERS.

## THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
DECEMBER 14TH, 1901.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on November 30th and that day.

### DEATH OF MESSRS. F. N. WARDELL AND W. BEATTIE SCOTT.

The PRESIDENT (Mr. J. G. Weeks) said that the Institute had been deprived by death of two of its honorary members—Messrs. F. N. Wardell and W. Beattie Scott. Both were H.M. inspectors of mines; indeed, Mr. Wardell was senior of the inspectors of mines, having been appointed in 1867. He had been connected with this Institute since 1864, and was at the time of his death a Vice-president of The Institution of Mining Engineers. They both graduated or served their apprenticeship in the collieries of this district: Mr. Wardell at the Tyneside collieries of Blaydon Main and Walbottle, and Mr. Scott in the neighbourhood of Etherley. He proposed a vote of sympathy and condolence with the widows and families of these gentlemen.

Mr. GEORGE MAY seconded the proposal, which was adopted.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. HUBERT HALLAM BIGLAND, Electrical Engineer, 10, Lish Avenue, Whitley, R.S.O., Northumberland.

Mr. WILSON S. CARR, Consulting Electric-power Engineer, 13, Mosley Street, Newcastle-upon-Tyne.

Mr. JOSEPH ARMSTRONG DIXON, Colliery Manager, Dunston Colliery, Gateshead-upon-Tyne.

Mr. EDWARD ECHLIN, Mechanical Engineer, Kabwet, Upper Burma.

Mr. EUGÈNE FIEUZET, Mining Engineer, 4, Rue Saint Blaise, Bagnères de Bigorre, Hautes Pyrénées, France.

Mr. GEORGE KELLETT FRYER, Colliery Manager, Shotton Colliery, Castle Eden, R.S.O., County Durham.

Mr. NICHOLAS RICHARDSON, Assistant Colliery Manager, South Ashfield, Newcastle-upon-Tyne.

Mr. JACOB SHARP, Colliery Manager, Lambton House, Fence Houses, County Durham.

Mr. ALFRED HENRY TAYLOR, Colliery Manager, Ngunguru Coal-mines, Kiripaka, *via* Auckland, New Zealand.

Mr. WILLIAM SHAKSPEARE WELTON, Mining Engineer, Elm Road, Wembley, Middlesex.

ASSOCIATE MEMBERS—

Mr. JOHN DAMPIER GREEN, 4, Palace Buildings, Johannesburg, Transvaal.

Mr. CHARLES W. H. SANDERS, The Avenue, Durham.

Mr. JAMES TONGE, jun., 149, Church Street, Westhoughton, Lancashire.

ASSOCIATES—

Mr. WILLIAM P. ARMSTRONG, Enginewright, Bewicke Main, Birtley, R.S.O., County Durham.

Mr. ROBERT BERKLEY, Deputy, 11, Co-operative Terrace, High Spen, Lintz Green, R.S.O., County Durham.

Mr. WILLIAM DODDS, Overman, Bewicke Main Colliery, Birtley, R.S.O., County Durham.

Mr. MICHAEL DODDS MCCARTHY, Engineplane-man, Fourth Street, Urpeth, Ouston, Chester-le-Street, County Durham.

STUDENTS—

Mr. EDWARD OTTO FORSTER BROWN, Mining Pupil, Westview, Cramlington, Northumberland.

Mr. ARCHIBALD DICKINSON, Mining Apprentice, 13, Matthew Street, Burnley, Lancashire.

Mr. GEORGE ATKINSON GILCHRIST, Apprentice Mining Engineer, 17, Eldon Place, Newcastle-upon-Tyne.

Mr. CHARLES HOWSON, Mining Apprentice, c/o Mr. Norman Nisbet, Harraton Colliery, Chester-le-Street, County Durham.

Mr. CHRISTOPHER LIDDELL, Mining Student, Woodhorn Colliery, Northumberland.

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Mr. R. H. Forster's "Memoir of the late George Baker Forster" was read as follows:—

# MEMOIR OF THE LATE GEORGE BAKER FORSTER.

By R. H. FORSTER.

Mr. George Baker Forster, who died on January 18th, 1901, was born at Haswell, in the county of Durham, on October 13th, 1832, his father, Mr. Thomas Emerson Forster, the wellknown mining engineer, being at that time the resident viewer of Haswell colliery.

Mr. Forster was educated at Shincliffe, under the Rev. Isaac Todd, at Repton school, and at St. Peter's school, York. In October, 1850, he went into residence at St. John's College, Cambridge, and in January, 1854, he came out in the Mathematical Tripos as a Senior Optime. It was on the river, however, that his chief distinctions were gained, and perhaps not the least valuable part of his education—his first experience in the management of men. Mr. Forster rowed bow in the Cambridge boat in 1853, when the Oxford and Cambridge crews met at Henley regatta as the only competitors for the Grand Challenge Cup. The race was one of the most exciting ever seen on the Henley reach; but in those days the course extended round Poplar Point to within a few feet of Henley Bridge, and Cambridge had the outside station. Oxford won by 18 inches, though Cambridge shot 6 feet ahead immediately after passing the post.

After leaving Cambridge Mr. Forster served an apprenticeship as a mining engineer, and began his lifelong connection with the coal-trade of the North of England. In 1858, he was appointed viewer of Cowpen colliery in Northumberland, which was in that year acquired by its present owners; and this position he continued to hold until his death—a period of over forty-two years. Shortly after his appointment to Cowpen, North Seaton colliery was amalgamated with the concern, as well as the coal-field underlying the Cambois estate in the same neighbourhood. New pits were sunk by Mr. Forster both on this royalty and on the Newsham royalty at Cowpen; and under his management the output of the combined collieries was raised from the small figure at which it stood in 1858 to that which it has recently attained, of over one million tons yearly.

Mr. Forster was also associated with the development of Blyth Harbour, for which he had been a Commissioner since the passing of the Act creating the Blyth Harbour Commission. The labours of that Commission, in which Mr. Forster took an active part, have conferred great benefits on the coal-trade of the neighbouring district, and have created a prosperous and commodious port, which is now entitled to rank with the Tyne and the Wear as one of the great coal-exporting harbours of the north-east coast.

Mr. Forster also sank and laid out Bearpark colliery, near Durham, and Longhirst colliery, near Morpeth, and he carried out extensive improvements at the Nunnery colliery, near Sheffield. In later years, he was consulting engineer to the Wallsend and Hebburn Coal Company, and superintended the important work of reopening the famous Wallsend colliery after a stoppage of forty years. This last was a work of much responsibility, since the colliery had been flooded and very extensive pumping operations were necessary to clear the pit of water.

In the West Cumberland coal-field, Mr. Forster, in conjunction with his father, for some years superintended Lord Lonsdale's collieries at Whitehaven; he also had business connections of long standing with the hæmatite ore-mines of the same county, and with the ironstone-mines of the Cleveland district.

In addition to his active colliery work, Mr. Forster had a very extensive practice as a consulting mining engineer, for a considerable time in partnership with his father, Mr. T. E. Forster, and the late Mr. T. G. Hurst, and latterly with Mr. T. E. Forster, his son. He was mineral agent to numerous royalty-owners in the North of England, and in 1890 he was appointed a member of the Royal Commission on Mining Royalties. The Commission had the rare distinction of presenting a unanimous report.

Coal-mining is not without its dangers, though happily the progress of scientific engineering has made those dangers far smaller than once they were. A serious colliery-accident is an event which entails great suffering and terrible responsibility, but it never fails to bring the nobler qualities of human nature into prominence. Even in lighter cases of accident Mr. Forster was always ready to afford valuable advice and active assistance, not only at the collieries with which he was personally connected, but in all places where his long experience and profound knowledge of mining could be of use. It is not many years since an underground fire broke out at one of his own collieries, and he spent the

whole of Christmas Day down the pit, watching and directing his men, as they turned the hose on the smouldering coal and then hewed it away till the heat called for the hose again.

But there were far graver occasions when all his powers were fully and freely exerted. He took a leading part in the work of rescue and restoration after the explosions at Seaham, West Stanley, Elemore and Usworth collieries,—a work of such responsibility as few men are ever called upon to undertake; for on the skill and judgment of the adviser depend the lives of many and the livelihood of hundreds. At an earlier period of his career, there occurred an accident which thrilled the country as few accidents have thrilled it since; and of the two who took the most prominent part in the attempt to rescue the entombed men at Hartley colliery, Mr. Forster was one.

It was on January 16th, 1862, that the disaster occurred. The colliery was worked by means of a single shaft, which for purposes of ventilation was divided by a brattice of timber. About the middle of the forenoon, the huge iron beam of the pumping-engine suddenly snapped at the centre, and the outer half of it plunged into the pit, killing five men who were at that moment coming up in the cage, and destroying the brattice, as well as injuring the sides of the shaft. The shaft was filled with many feet of tightly compressed wreckage, and there were a hundred-and-ninety-nine men and boys in the workings below.

It was only a few hours later that Mr. Forster reached the scene of the accident, and he at once took the leading part in directing the work of rescue, which Mr. William Coulson, the master-sinker, was called in with his men to attempt. There were strong hopes that the imprisoned men would live for many days, and the work of clearing the shaft was pressed on with extraordinary energy, day and night without cessation. But the dangers and difficulties were appalling; the sides of the shaft had been seriously damaged and threatened to fall in upon the workers, so that much precious time had to be spent in securing them, and much of the wrecked timber had been pounded into such small fragments that it had to be dug out with shovels. The anxious crowds that waited at the pit-mouth began to murmur at the slow progress of the work, and there were not wanting wiseacres who aggravated the horrors of suspense by declaring that the management was hopelessly at fault, and propounding various useless and chimerical schemes of their own invention.

But still the work went on, and still there was hope; the imprisoned men had a certain amount of food, and there was good water in the pit. Presently, however, a thing happened which told those who knew that there was little chance of saving the men alive. Gas began to leak up through the wreckage in such quantities that many of the sinkers had to be carried out of the pit unconscious, and its effect on the candles of the workers showed that it was carbonic oxide, a deadly poison. If the men below had breathed it, they must have been dead days ago; and eventually the fear proved only too well-founded.

From this time the work was carried on with increased difficulty; for it became necessary to construct a cloth-brattice down the upper part of the shaft, to restore the ventilation and draw the gas away; but at last, seven days after the accident, the first explorer penetrated to the place where the men had gathered, and waited, and died; and it was not until three more days had passed that it was possible to bring their bodies to the surface. All that men could do had been done; for a week the rescuers had been risking their lives; and after all they had failed.

To show Mr. Forster's share in the work, we need only quote from the report of the evidence which he gave at the inquest; for in speaking of the dangers and exertions of the men he has unconsciously borne testimony of himself:—

Coroner: Did you go down the shaft, Mr. Forster?—I did, sir.

You perhaps went several times down?—I did, sir. I was down on Thursday night first.

Until Mr. Coulson and his men came to take charge of it?—Oh, I went down with Mr. Coulson afterwards until the bodies were found.

The work was very dangerous for the men, was it not?—Yes, very dangerous for the men.

Timbers were constantly falling?—Yes.

Was every effort made that possibly could be made to get to the men?—Everything was done, sir; nothing was shrunk from.

And without heeding danger?—No, the men never flinched.

Do you believe that anything further could have been done effectually?—I do not.

If more words be needed, let them come from the jury, whose verdict contained the following clause:

They also take occasion to notice with admiration the heroic courage of the viewers and others, who, at the risk of their own lives, for so many nights and days, devoted their best skill and energies to rescue the unfortunate men who were lost.

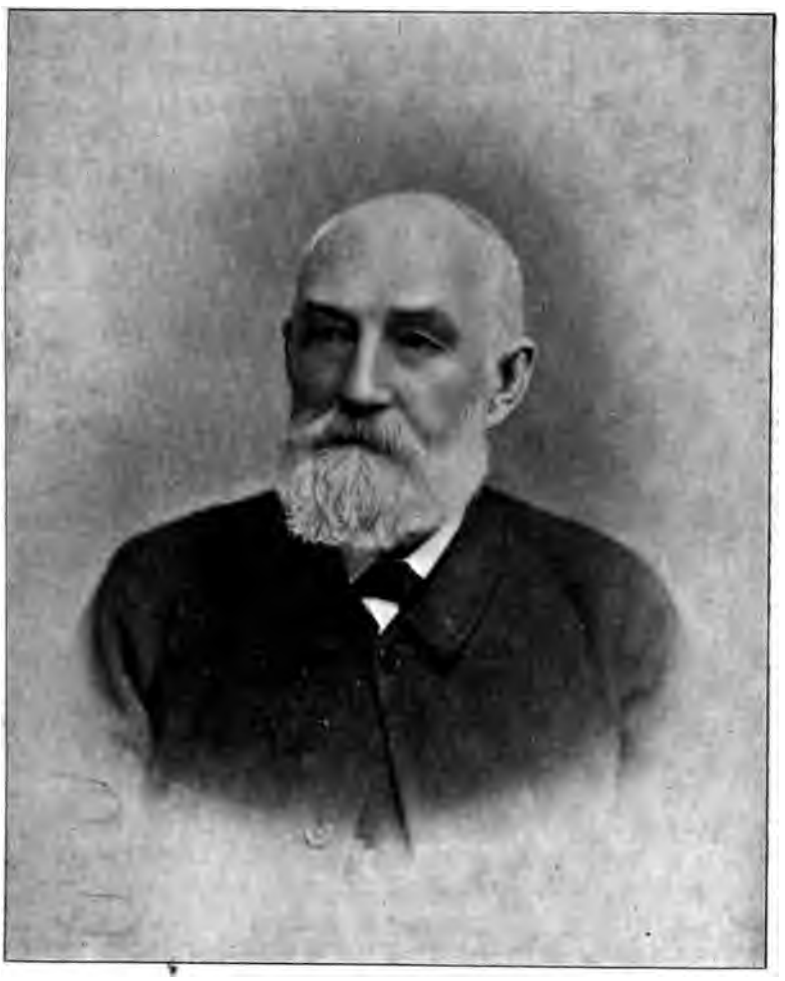
The widows and orphans received a touching message of sympathy from Her late Majesty Queen Victoria, herself a newly-made widow,—the first message of the kind that broke the silence after the Prince Consort's death, and to this day the printed copies of it which were distributed form the most treasured possessions of the few widows that still survive. It is a pathetic coincidence that the same January day saw the brave engineer, who left home and business to direct the work of rescue, laid to rest almost within sight of the scene of the accident, and saw also the passing away of the gracious Lady, who in the first weeks of her widowhood remembered the sorrows of humbler women, and sent them comfort in their affliction.

In the coal-trade of the North of England Mr. Forster held an unequalled position, and exercised a wide and beneficent influence; to quote the resolution, which the Miners' Association of Northumberland passed on hearing of his death, he was a pioneer in the promotion of harmonious relations between capital and labour. He was Vice-Chairman of the Northumberland Coal-owners Association, and also of the North of England United Coal-trade Association. He was from its commencement a member of the Northumberland Joint Committee,—a representative body of masters and men which has been the means of settling countless questions on matters of colliery-working; and he was also a member of the Conciliation Board for the regulation of wages in the same county. In 1857, he was elected a member of this Institute; he became President in 1881, and held the office for a term of three years. He was also a member of the Institute of Civil Engineers and a Fellow of the Geological Society. He was a Justice of the Peace for the county of Northumberland, and for a long period Chairman of the Magistrates for the Blyth Petty Sessional Division. He was for many years a member of the Board of Examination under the Coal-mines Regulation Acts, and an examiner of applicants for certificates of competency under the same Acts.

Mr. Forster was the first chairman of the School Board established at Cowpen after the passing of the Education Act of 1870, and he held that position without interruption for a period of twenty-one years, retiring in 1892. But throughout a career which began long before the days of public elementary education, he took a deep and broad-minded interest in educational

matters, and especially in such as tended to place the means of practical scientific education within the reach of working-men. He established schools at all the collieries under his charge, as well as Mechanics' Institutes, of which he was a hearty supporter; but while he took an active interest in everything that promoted the well-being of his men, he wisely encouraged self-help and self-reliance, as is shown by the following instance, which is still remembered by those who reaped the benefit of his wisdom. In 1872, there was an epidemic of scarlet fever at one of the colliery-villages, which was found to be caused by bad milk, and a deputation of the men came to Mr. Forster to ask whether the colliery-company could not undertake the duty of providing a better supply. Mr. Forster told them that this was not within the company's powers, but he suggested that the men should join together and start a co-operative dairy-farm of their own; there were two fields included in the lease of the colliery, and he promised that the company would make them tenants of these fields at the same rent as was paid to the lessors, and would also erect the necessary buildings, charging only a low rate of interest on the outlay. The suggestion was adopted and carried into effect; the farm was started and managed by a committee of the men, and to this day it continues a useful and profitable institution.

With the men employed at the collieries, Mr. Forster's relations were always of the happiest nature, and he was never so pleased and interested as when his duties brought him into direct contact with the colliery-officials and workmen. While he did all that lay in his power to promote the interests of the owners, he never failed to consider the welfare and the feelings of the men; and in his management he was conscious of a bond between himself and those who served under him, which was better and more enduring than the bare legal relation of employer and employed. He had also the rare capacity of arousing enthusiasm in his subordinates; some of his colliery-officials had been with him for forty years, and their feelings towards him were of the most devoted attachment. He possessed in a high degree the tact and sympathy which workmen, and especially those of the north, readily understand and appreciate; and above all his dealings with them were marked by a spirit of absolute fairness, and a most scrupulous regard for truth and justice. These characteristics won him, in a degree which few employers have ever enjoyed, the esteem and confidence not only



GEORGE BAKER FORSTER,

PRESIDENT OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS, 1881 TO 1884.

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*Born October 13th*, 1832, *and died on January 18th*, 1901.

of his own men but also of all the workmen of the surrounding districts.

Mr. Forster was married in 1854 to Hannah Elizabeth, elder daughter of the Rev. Isaac Todd of Shincliffe, and leaves a family of four sons and three daughters.

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Mr. A. L. STEAVENSON moved a vote of thanks to the writer of the memoir of a friend whose loss they all so greatly deplored; he was sure that future generations would be glad to have so excellent a record of his useful life. The memoir was an interesting one, but they could have expected no less from a writer of such ability as Mr. R. H. Forster, who was the author of *The Hand of the Spoiler.*

Mr. W. O. WOOD seconded the vote of thanks, which was cordially adopted.

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Mr. W. C. BLACKETT read the following description of "A Method of Socketing a Winding-rope, and its Attachment to a Cage without the Use of Ordinary Chains":—

# A METHOD OF SOCKETING A WINDING-ROPE, AND ITS ATTACHMENT TO A CAGE WITHOUT THE USE OF ORDINARY CHAINS.

By W. C. BLACKETT.

Before proceeding with these few notes, the writer would allay possible criticism by specially disclaiming any novelty. It is true that he had a patent (long since expired) in connection with one of the appliances described, and he brings the subject forward as one of everyday interest to many to whom more recondite subjects do not so closely appeal.

*The Socket.*—For many years, the writer had distrusted the commoner methods of capping ropes, wherein the hold depended upon the bending back of the wires. Nevertheless he, like many mine-managers suffering from the personal burden of the Coal-mines Regulation Acts, found it difficult to break away from what was a well recognized ordinary method, and to undertake the responsibility which accompanies the introduction of the locally unconventional.

It always appeared to him that such a method as bending back various lengths of wires around the end of a rope, so as to form a more or less conical end, subsequently capped by a socket, was utterly unscientific, and could not by any possible means be made even nearly to approach to the tensile breaking-strain of the rope. The hold entirely depended upon the frictional clasp around the rope, *plus* an unknown transverse strain at the bend of the wires.

Experiment proved that such a capping often only bore a ratio of from 50 to 60 per cent. of the breaking-strain, and it seemed folly to be so careful as to getting ropes with a margin of safety of 10 to 1, and then to throw much of it away in socketing. Tests proved that the rope, so capped, invariably drew out of the

FIG. 1.—OLD FORM OF ROPE-SOCKET AND WALKER SAFETY-HOOK.

FIG. 2.—NEW FORM OF ROPE-SOCKET AND WALKER SAFETY-HOOK.

socket, with a long, torn-out, frayed end of wires. With the form of socket to be described, the rope was invariably broken just within the socket, at strains varying from 80 per cent. and upwards of the full breaking-strain.

The writer, therefore, adopted it, and Figs. 1 and 2 show the old and the new forms. To those who happen to use Walker safety-hooks, it will be a matter of interest to notice that the jaws of the socket are made to engage direct into the jaws of the hook, the links, A (Fig. 1), which usually accompany the hook, having been dispensed with.

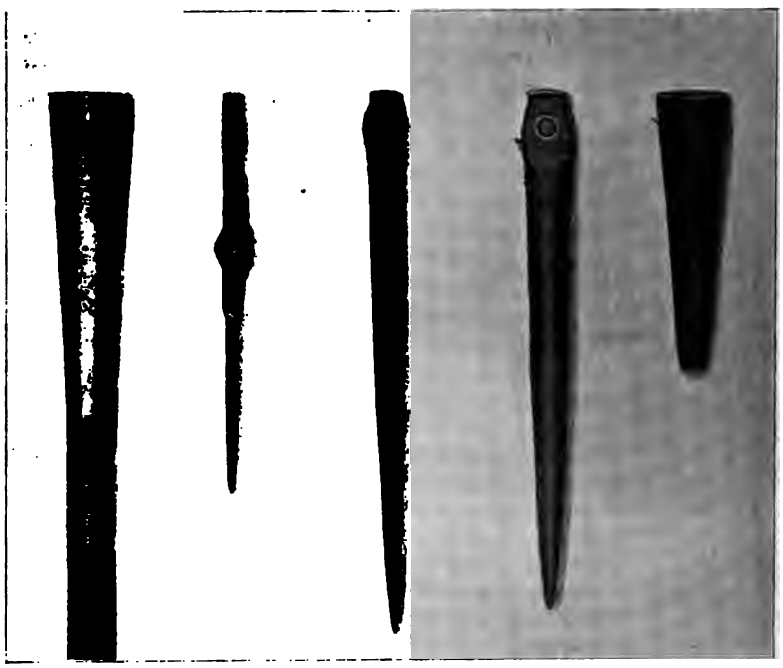

FIG. 3. FIG. 4. FIG. 5. FIG. 6. FIG. 7.

The socket is a hollow cone made from a solid forging of Low Moor iron. The sizes given for a 70-ton rope are shown in Fig. 9 and are probably somewhat greater than necessary. Into this hollow cone, about 9 inches of the ends of the wires of the rope are carefully and evenly spread out, and then fixed in their position by running in good white metal. The end of the rope is then practically a solid cone (an actual end was produced for inspection) which cannot be drawn out (Fig. 3).

The method of capping is as follows:—The rope-end having been inserted through the small end of the socket and tightly

FIG. 8.—DIRECT ATTACHMENT OF ROPE TO CAGE.

clammed, about 1 foot of the rope (next to the 9 inches which are

to be subsequently spread out) is very carefully wrapped with copper-wire and the rope-end then drawn back so that the loose wire-ends are within the cone in the position that they are intended to occupy.

A steel-point (Fig. 4) is driven into the centre of the rope, to effect the primary spreading of the wires. This point is then withdrawn, and another steel-point (Fig. 5) inserted, which spreads the wires still further. This is in turn removed, and its place is taken by a larger steel-point (Fig. 6), first alone and again with the funnel (Fig. 7) around it, forming a sort of trocar. Thus, the funnel is driven in as far as possible and its threader removed, leaving the wires spread out to their fullest extent by the former alone, and then they are carefully wiped as clean as possible.

The white metal is then run down through the funnel, so that the innermost end of the cone may be reached when the funnel is withdrawn, the metal run in further to fill the whole socket, and so complete the operation.

The metal is melted out to re-socket the rope.

*The Direct Attachment.*—It may be that, like the writer, some of the members have found a difficulty in arranging head-room for the cage-chains, when circumstances have rendered it necessary for the cage to be enlarged or lifted higher without also raising the pulleys. In such a case, the writer can recommend, at any rate with cages having more than one deck, that the chains should be dispensed with altogether (Fig. 8). Figs. 9, 10, 11 and 12 illustrate how this may be done, by adding to the cage-top triangular webs of iron, Z, which carry at their apex a cross-bar, Y. Through the centre of the cross-bar, Y, passes a single-eyed bolt, X, which is provided with a buffer-spring made of iron-cups, W, and indiarubber rings, V, which serve to take up the shock at the lift of the load. Between the Walker safety-hook (in this case) and the buffer-bolt, X, are such shackles and links as may be thought necessary.

The writer, at first, used only one large oval link between the two sets of shackles, but subsequently he was obliged to add three or four more, because it was found that the impact of the safety-hook upon the shackle of the buffer-bolt, when the descending cage struck upon the bottom, was sufficient to shear through the copper-pins holding the hook-thimble in its place. The inter-

position of the extra links, however, cured this defect and provided adequate freedom of movement.

It will be observed that Fig. 8 shows short bridle-chains hang-

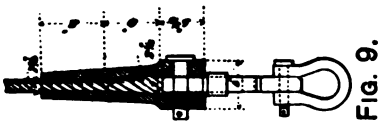

Fig. 9.

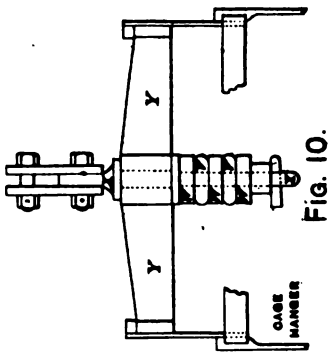


Fig. 10.

Scale, 2 Feet to 1 Inch.

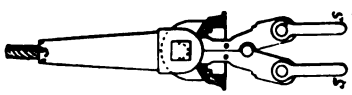

Fig. 11.

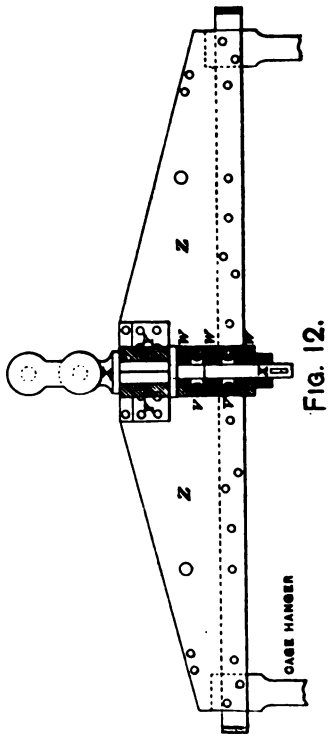


Fig. 12.

ing, quite slack, from the hook-shackles to the corners of the cage. They are quite unnecessary, although perhaps providing some slight additional safety, and were added as an afterthought to satisfy the prejudices of the workmen.

The cage runs smoothly in wooden end-guides, and as steadily as ever it did with ordinary chains.

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Mr. A. L. STEAVENSON agreed with Mr. Blackett that rings were a great improvement upon hangers for attaching the rope to the cage. Chains became unevenly balanced, as the through-bolts were continuously exposed to shocks.

Mr. HENRY LAWRENCE said that at one of the deep pits in the neighbourhood of Birmingham, he had seen an attachment which consisted of a taper-socket, with the wires of the rope turned back, and without any other fastening. The members were indebted to Mr. Blackett for bringing before them the result of his experience. He had pleasure in proposing a vote of thanks to him for his valuable paper.

Mr. PHIL. KIRKUP, in seconding the motion, said that at the aerial ropeway at Malton colliery, in the county of Durham, a similar system of socketing the ropes was in use. The ends of the carrying ropes were put through a conical steel-casting, white metal was run in, and he believed that the arrangement was entirely satisfactory.

The vote of thanks was cordially approved.

Mr. W. C. BLACKETT, in acknowledging the vote of thanks, said he would like to emphasize the fact that he did not claim any novelty for the method described. Some 15 or 16 years ago, he took out a patent in connection with the socket, and the question of its being no novelty was raised even then. The sockets had been the only ones in use for many years on the hauling-ropes at his collieries, and where it was not practicable to run in white metal, copper-plugs were driven in.

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## DISCUSSION OF MR. F. O. SOLOMON'S PAPER ON "THE FEEDING OF HORSES, WITH SPECIAL REFERENCE TO COLLIERY STUDS."*

Mr. F. O. SOLOMON referred to the remark made by Mr. Blackett, at the previous meeting, that "he did not altogether approve of using a larger proportion of maize than oats,

* *Trans. Inst. M.E.*, 1900, vol. xix., page 279; and 1901, vol. xxii., page 152.

although there was perhaps no great harm in it."* Besides the objection which Mr. Blackett mentioned, namely, that of causing skin-irritation, maize when fed in large quantities had the effect of rendering the odour of the fæces objectionable, and this might be particularly noticeable in underground stables. With regard, however, to the perfect safety of feeding a larger proportion of maize than oats, he thought that there could be no question, and the saving in cost thus effected had of late years been very considerable. As a matter of fact, he found comparatively few instances amongst the colliery-stables that he was privileged to visit in which the oats formed a larger percentage by weight of the mixture than the maize. He had a few statistics of colliery-feeding returns now before him, and selecting a couple indiscriminately he found that in one case, where over 500 ponies were kept, the maize and oats were present in the proportion of 30 per cent. and 18½ per cent. respectively. In the other instance, where rather over 80 animals were kept, the allowance of these two cereals worked out at 3·02 pounds of oats and 5·72 pounds of maize per head per day. Again, Mr. J. G. Weeks spoke approvingly of a mixture containing 35 per cent. of maize and 20 per cent. of oats. He believed that, if circumstances made it worth while, maize could be, if not wholly, very largely substituted for oats, provided that pulse-grain was used along with the maize, in the ratio of 3 of the maize to 1 of the pulse. And, as stated in his paper, 15 hundredweights of this mixture would be equivalent in feeding-value to 19 hundredweights of good oats. As to the quantity of food necessary per 1,000 pounds weight of animal, it would be noticed that his estimate was derived from the allowances of food made for omnibus, tram and cab-horses. He quite thought that aboveground horses were allowed rather more weight, though not more nourishment, than underground horses. One reason for this was that a greater proportion of the more bulky foods, like hay, was used, because the food had to be less handled and shifted about. For collieries, it was obviously important to have as small a bulk as possible to manipulate.

Again, the matter of waste was not so carefully attended to in stables aboveground, and this point was closely associated with the proportion of hay, as this latter was much more dusty and wasteful

* *Ibid.*, vol. xxii., page 152.

than corn. In Mr. Blackett's own case, as he once had an opportunity of observing, the minimum allowance for actual consumption can be made:—(1) Because the rations are very concentrated in character, and composed of high-quality materials; and (2) because of the excellent system which was carried out of screening, mixing, serving and preventing waste. He was much interested in Mr. Blackett's suggestion to take the girths of horses, and had wondered whether the 1,000 pounds weight of horse of which he spoke was the actual result of weighing or of calculation from the girth.

Regarding Mr. J. G. Weeks' reference to the proportion in which the different ingredients in a ration should be mixed, he saw no serious discrepancy between Mr. Weeks' figures and his own. The proportion of hay indicated by him was lower, and in consequence rather less weight of food would be required per horse. The matter would be chiefly controlled by the relative prices of hay and corn ruling in any given year. Mr. Weeks' proportion of maize to pulse was roughly 37 to 13, and his own was 31 to 10½, a ratio in both cases of about 3 to 1.

Mr. PHIL. KIRKUP said that the paper written by Mr. Solomon was a valuable contribution on a very important subject, but it treated it very scientifically and perhaps a little more theoretically than practically, and as a result would not prove quite so useful to the every-day colliery-manager. He had discussed the various points raised in the paper and in the discussion, with the Birtley Iron Company's veterinary surgeon (Mr. John Aitken) and he generally agreed upon the main points. Feeding on a basis-system was an extremely difficult one, but the regulation of this according to the height was more reliable than that proposed by Mr. Blackett of taking the girth. It was usual to judge the capacity of a horse for work by its height. A standard for food arrived at even by the heights of animals was not always reliable. He knew of instances, in their own stables, where an animal of a certain size would eat from 2½ to 3 stones of mixture more per week than others of a similar size. The definition of a standard basis and the ration-tables were very useful for approximately arriving at the quantities and cost of feeding of large studs, but they should be taken merely as a guide. The President (Mr. Weeks) made some very pertinent remarks with which he sub-

stantially agreed. The only practical method of feeding horses was according to the amount of work which they had to perform. The food should be of good quality, and mixed in proper proportions, and not too concentrated a mixture, as it was necessary for proper digestion and the well-being of the animal that he should have a fair proportion of bulky non-nitrogenous food to fill the bowels. He was of opinion that the late Mr. Hunting, as a rule, adopted too concentrated a mixture, the tendency being a high death-rate from gastro-intestinal diseases. He did not agree with Mr. Weeks when he said that a horse should have as much food as he could eat, and in many cases the result would be disastrous, as there were animals that would kill themselves were this idea carried out.

Mr. Solomon gave tables of the comparative value of maize over oats, with regard to the ratio of carbohydrates and their value, but he did not remark upon the effect on the animal-economy of this feeding which pointed to his paper (as he said before) being more theoretical than practical. Mr. Blackett seemed to recognize that there would be something wrong as "he did not altogether approve of using a larger proportion of maize than oats, although there was perhaps no great harm in it."* He remarked that in some cases maize showed a very peculiar effect in "heating the skin, but he did not think that this was of sufficient importance, etc."† Now, their own experience with a stud of 500 animals had shewn the dangers attending the excessive use of maize in mixed foods. It was undoubtedly a fruitful source of laminitis, disease of the liver, diarrhœa, irritation of the skin associated with grease, and gastro-intestinal diseases.

With regard to the mixing of the food, he thought that the best plan was to have the grain and the hay thoroughly incorporated in the chopping and grinding process before being filled into the sacks, and if this were properly carried out the mixture would retain its uniformity. Within reasonable limits and with strict regard to the horses' internal economy, the proportion of the different ingredients in the food could be varied with the market prices. At the present time, maize was dear and oats were cheap. The mixture at their collieries at present was as follows:—1 ton of hay, 26 bolls of oats, 12 bolls of maize, and 4 bolls of beans.

The quantities allotted to each stable per head were as follows:—10 to 12 hands, 5½ stones per week; 12 to 14 hands, 8

* *Ibid.*, vol. xxii., page 152. † *Ibid.*, vol. xxii., page 153.

stones per week; and 14 hands, 11½ stones per week. The horse-keepers had a certain amount of discretion as to the quantity to be given to each animal, according to the individual animal's capacity for food and his work, be that easy or laborious. The food taken by an animal bore in some measure the same relation as coals to a boiler. They could not expect heat—which in both instances meant work—without fuel, and therefore the more work that either the animal or the boiler had to perform, the greater would be the consumption of food in the one case and of fuel in the other.

Mr. W. C. Blackett said that one or two matters of interest had arisen on the question of feeding of horses that had not been previously discussed. He would like to add a few words in defence of his recent method of estimating an average horse, and it seemed to him that Mr. Kirkup's last simile was probably the best basis that he could take to strengthen his own argument, for that gentleman had compared a horse to a boiler. Even Mr. Kirkup, or whosoever had any doubt about the method of girthing a horse to arrive at his comparative average strength or capacity, would admit that it would not be desirable to estimate the power of a boiler by measuring the height of the stand or settings on which the boiler was placed, and that was exactly what was done when they measured the height of a horse, for they were only measuring the height of the boiler upon the horse's stands or legs. He would suggest that it was much more nearly a fair comparison to measure the furnace-area or heating-area of a boiler and the furnace-area or heating-area of a horse, and that was most distinctly round his chest, which contained the heart and lungs. It had been mentioned to him that really he had only chosen a method of measuring a horse that was used for measuring cattle. But the measurement of cattle was merely taken as a guide for ascertaining their weight, and weight was not a good guide for a horse, for a horse might be heavy at one time and light at another. What did not vary greatly was his chest-capacity: this was practically constant, and was more or less comparative with the furnace-area in the boiler. Mr. Kirkup said that he had found a difference between two horses, even of the same size; and no doubt that would be so, for a stout animal on short legs was better than a thin one on long legs.

With regard to the method of giving large proportions of

maize, he wished rather to reserve his opinion. Horses had their own idiosyncrasies, but undoubtedly maize had an effect on the skin of some of them. He admitted that the number was small, and he was not, at present, inclined to condemn the use of large quantities of maize. He had used maize, for a number of years, in varying proportions with oats, without finding any serious difference.

He had heard it suggested that any fault in feeding was put down to gastro-intestinal troubles, and very frequently the death of a horse was attributed either to this or to inflammation, but by far the most dangerous cause was not in the feeding, but was due to a small, red, blood-feeding worm, $\frac{3}{8}$ to $\frac{1}{2}$ inch long, called *Strongylus tetracanthus*, which bored through every organ in the body of a horse, and was far more common than was supposed. It was difficult to trace, unless very great care was taken in the *post-mortem* examination. He was convinced that this was the cause of death in many cases, where horses were supposed to have died from so-called inflammation or alleged improper feeding. He had seen this worm in the walls of the bowels and stomach, and in the mesenteric artery, and even in the lungs. Their life-history was not known, and he was not sure that they were not born in the foal through the blood, and that accounted for many young ponies dying. It was very necessary for a colliery-manager to look into his stock, and after intestinal troubles to have *post-mortem* examinations. The worms would be found as thin as a hair, and up to full size. He thought that it was possible to cure a horse, but he was not sure; however, a horse could be kept alive for a great number of years, if precautions were taken after the presence of the parasites had been discovered.

Mr. C. W. C. Henderson said that it was difficult to draw a hard-and-fast rule with regard to the feeding of horses. Taking two horses of exactly the same measurement, one would do more work than the other and would do well, while another one would not. They should encourage the horsekeeper to use his discretion, and when a horse would not feed to induce him to do so, and to watch an over-feeder and prevent him from feeding too much. He was of opinion that a horse should be supplied with almost as much as he could eat.

Another point was the necessity for inbye feeding in the middle of the day. It had been the practice at a great many pits

to send the ponies' food inbye, and to give them both food and water there. This was a great help, for often in the old days a pony did not get any food from the time he left the stables in the morning until he returned at night. The members were all greatly interested in anything that could encourage the welfare of horses and ponies, and this matter had of recent years taken great strides. The subject was a useful topic for discussion, and he hoped that it would lead to everyone, in the future, taking more pains with their horses and ponies.

Mr. J. H. MERIVALE said that for many years he had been in the habit of having the horses and ponies regularly examined and girthed, and he had given prizes to the putters and drivers according to the condition of their animals. He did not necessarily give these prizes for the horses which were in the best condition, for this might not be due to the boys but to the work. The condition of the horses and their work was considered, and prizes were given accordingly. When he started the prize-scheme he thought that it would tend to encourage the boys to take an interest in their horses and ponies, and now that he had given the matter a fair trial for some years he was not sure that it had had this effect. It had, however, this advantage, that the boys knew that at least every quarter the manager and the veterinary surgeon would inspect the animals and girth them, and if any were found to have anything the matter with them, the boys in charge would be taken to task.

Mr. C. C. LEACH said that the most important man about a pit-stable was the horsekeeper, and if they got a good countryman with a "horsey eye" in his head, the horses would keep well, but if not he thought that the reverse was likely to happen.

The PRESIDENT (Mr. J. G. Weeks) desired to correct certain figures which had been attributed to him. An animal over 14½ hands he considered as a horse; under 12 hands as a pony, and two of these as equal to one horse; and between 12 and 14½ hands he considered as a galloway, three of these being reckoned as two horses. With that method of measuring, he found at the Bedlington collieries that their consumption, taken over the last 8 years, was 21 pounds of corn and 9 pounds of hay per horse per day. This was a sufficiently long period to form a very fair basis. When he stated that he would allow a horse to eat as much as it would take of its own accord, he must not be understood to be encourag-

ing gluttony on the part of the horse, for he would trust to the discretion of the horsekeeper to see that the horses were neither stinted nor overfed, but were allowed sufficient for their work.

He could not see how the giving of prizes to boys would have the effect of increasing their interest in the horses and ponies. The horsekeeper was the more important element in the matter, and instead of getting an old man, or a shifter, to look after the horses, it was desirable, as had been suggested, to obtain the services of a countryman with a knowledge of horses. In his own case, he had been fortunate in having good horsekeepers, upon whom much depended. A good deal also depended on the health of the animals, and the suggestion of Mr. Henderson that food should be taken inbye during the day would prolong the life of the ponies and maintain them in excellent condition. At his own collieries, both food and water were taken into every district in the pit in the middle of the day. The animals did not eat any more in consequence, and they performed the work more efficiently.

Another great error was to send ponies down into the mine when too young: they should not be less than 4 years of age, but 5 years was preferable.

With reference to the mixture proposed by Mr. Kirkup, he thought if that gentleman converted his proposal into figures, he would find it more expensive than the proportion which had been advocated at the previous meeting. In looking over the statistics connected with the Bedlington collieries, he found that the largest proportion of maize given to the horses was in 1887, when the feed was 44 per cent. of maize and 36 per cent. of hay, 7 per cent. of peas and 13 per cent. of oats, but that was during the year of the miners' strike, when the animals were not working for 17 weeks, and they simply gave them a larger quantity of hay and maize instead of the usual 30 per cent. and 36 per cent. respectively, the expensive food—oats and beans—being stopped. The animals at the end of the 17 weeks' strike, having more or less daily exercise at bank, were in thorough working condition, and were taken to work into the pit at two days' notice.

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A paper by Mr. EDWARD HALSE was read on "Some Silver-bearing Mines of Mexico."*

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* This paper will be printed in a later issue of the *Transactions*.

# MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD,
FEBRUARY 1ST, 1902.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

## DEATH OF MR. F. N. WARDELL.

Mr. W. H. CHAMBERS proposed that a vote of condolence be sent on behalf of the members to the widow and family of the late Mr. F. N. Wardell, H.M. inspector of mines. Everyone acknowledged the great benefits that had accrued to the district through his wise administration; he was always willing to advise to the best advantage, his earnest desire was to maintain a high state of efficiency in the mines of his inspection district, and the legislature had borrowed the practices that had been adopted through his advice to ensure the safety of the mines and of those employed in them. He felt very deeply the sorrowful nature of his task and it was with very great regret that he performed the necessary duty that day.

Mr. JOHN NEVIN, in seconding the motion, said that he had known Mr. Wardell since 1868, when he was serving his apprenticeship, and he could state that he had always received the greatest consideration and the greatest kindness from him, and he was sure that every colliery manager in Yorkshire would endorse his statement.

The PRESIDENT (Mr. John Gerrard) said that he entirely agreed with every word that had been so well said. A kinder-hearted, more genial, more able inspector of mines than Mr. Wardell it was not possible to conceive; he knew him so well, and so long, that he could not trust himself to say what perhaps, he might otherwise have said.

The resolution was carried, every member present standing.

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The minutes of the previous General Meeting were read and confirmed.

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The following gentlemen were elected, having been previously nominated:—

HONORARY MEMBER—

Mr. W. H. PICKERING, H.M. Inspector of Mines, Doncaster.

MEMBERS—

Mr. FREDERICK SEPTIMUS BRUNTON, Civil Engineer and Surveyor, 35, Norfolk Street, Strand, London, W.C.

Mr. A. HAMPSHIRE LEE, Mining Engineer, Covenham House, St. John's, Wakefield.

Mr. JOHN JAMES PATTISON, Manager, Batley and Morley West End Collieries, Batley, near Leeds.

Mr. WILLIAM PATTISON, Manager, Morley Main Collieries, Morley, near Leeds.

Mr. ALFRED RHODES, Mechanical Engineer, Hick Lane, Batley.

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Mr. ALEXANDER REID read the following paper on "Chinese Mines and Miners":—

# CHINESE MINES AND MINERS.

By ALEXANDER REID.

The writer has frequently been informed by old China hands, or gentlemen who have resided for such periods as up to 35 years in the Celestial Empire, that they have failed to fathom the Chinese mind or clear their view of that complex individual—the Chinaman. It is, therefore, reasonable to bring before the members a few first impressions of Chinese miners and their mines, as the result of a series of interesting journeys in China, with an apology at the outset, on behalf of the now defeated Boxers and misguided Chinese officials for their interruption of interesting investigations and for their disapproval, for the moment, of the introduction into China of the methods of the West.

After a rather stormy journey, and a somewhat exciting welcome to the country, as it was the writer's misfortune to start from the city of Tientsin just as the wave of anti-foreign rebellion was moving northward and the Society of Harmonious Fists or, as the foreigners term them "The Boxers," were getting out of hand, the coal-fields of northern Honan were reached in the middle of June, 1900.

## Northern Honan.

The country passed through from Tientsin to the Yellow river, by way of the Grand Canal and the Wei river to the city of Hwai-King, is one vast plain, and the first view of the mountains of Shansi is welcomed as a change from the monotony of a three-weeks' journey in the flat country.

The Honan coal-field, north of the Yellow river, is developed by the Chinese along the base of the Tai Hang range of mountains, which rise abruptly and form the frontier of the province of Shansi. Baron F. von Richthofen, the eminent German geologist, whose

writings are the only standard works upon the geology of China, describes this Tai Hang range as not a mountain-range in the usually accepted sense of the term, but as the edge of the plateau of Shansi. The formation is a most wonderful one, and interesting in its simplicity. From the vast plain of Honan rises abruptly the Tai Hang range to an elevation of about 2,500 feet, and the elevated plateau generally maintains or exceeds that elevation throughout southern Shansi. Along the north-western boundary of the Honan plain, the coal is worked in the foot-hills, that fringe the principal rise, and it would seem that a vast coal-field, awaiting development, must extend to the east of the Shansi barrier, beyond the belt of the coal-field worked in the fringe of the foot-hills (Fig. 1).

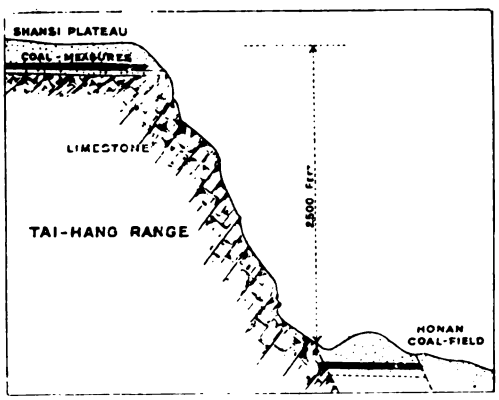


FIG. 1.

Underlying, the coal-formation is an enormous mass of limestone, generally bluish in colour. In the Lower Coal-measures, a little seam is found, but it is generally inferior in quality and high in sulphur-content. Overlying the seam is a bed of massive limestone carrying flint-nodules, and this is in turn succeeded by clay-slates and sandstones, in which the principal coal-seam (20 feet thick) is found. The analysis shews that it contains about 88 per cent. of fixed carbon, 4 per cent. of volatile hydrocarbons, 7 per cent. of ash and ½ per cent. of sulphur. The ash is generally of a buff or light-grey colour.

The Lœss formation overlies the Coal-measures in several places, and near to the mines, the writer saw people dwelling in houses excavated in the Lœss. Chimneys are rarely seen in Chinese houses, but in the Lœss cave-dwellings a hole in the roof serves as chimney and ventilator. Lœss is a kind of yellow, homogeneous, unstratified loam, but owing to the presence of innumerable rootlet-holes, traversing it downwards, it has a somewhat vertical cleavage. There are roadways in the Lœss country, over 100 feet deep, with walls of Lœss standing nearly vertical,

on either side. The Lœss is stated to be a wind-drift deposit, but its homogeneous character seems to suggest the presence of a powerful extraneous binding-agent not so readily accounted for. The Lœss is found of great thickness to the south of the Yellow river. The passage of cart-traffic along its roads cuts deeper in time, and the disintegrated dust is often blown about by wind-storms, much to the inconvenience of travellers, for the dust is as fine as flour. A short spell in a dust-storm makes one feel as if a bag of fine flour had been emptied over one.

The coal-mines in the northern Honan districts are generally entered by means of shafts, varying from 200 feet to 300 feet in depth. The coal is anthracitic, with a conchoidal fracture, and has a ready sale for domestic purposes; in the Tai Hang foot-hills the present output is about 5,000 tons per day. The principal coal-seam varies in thickness from 6 to 20 feet and lies nearly horizontal. The shafts are generally about 5 feet in diameter, and are unlined in strong ground; but in broken ground, they are secured by timbering and cased with basket-work. The winding-apparatus is a simple winch, with a drum about 18 inches in diameter placed over the centre of the shaft. No guides are used, and the coal is drawn in baskets, made of bamboo, and carrying about 133 pounds. The writer was lowered into the mines sitting on a spar attached to a rope, which he had the precaution to have first tested by the lowering down of a Chinese foreman, who was well built and a fairly weighty man.

No system of surveying seems to exist in this district, and each mine is worked as far as possible from its shaft. The system of working is pillar-and-stall. The ventilation is natural, and not particularly good. Fortunately, the mines in this district are not much troubled with fire-damp.

The miners are well-built men, and in the practical detail of their operations seem to be thoroughly capable of taking care of themselves.

The mining operations of this district, as with other districts in China which the writer had the opportunity of inspecting, gave him the impression that the Chinese characteristic of " not being in a hurry " was a great advantage where legislation did not exist to compel the miners to take precautionary measures for their own safety. Timber is imported from other districts; and with no

facilities for transport it is expensive and has to be sparingly used, and no doubt in taking advantage of the natural supports afforded by the coal itself much coal is left in the mines.

The Chinese are essentially handy-men and inventive up to a certain point, but where steam and electric power are required, the Chinese find themselves absolutely stopped in their own mining operations. In the Honan coal-field, there is a serious difficulty with water, and although devices for winding water by hand are well carried out, mining operations have to stop where water in any quantity has to be raised. They have small water-tanks, carrying about 15 gallons, running on guides, and so arranged that they tip and empty themselves automatically, when they reach the top of the shaft. But hand-labour has no chance in dealing with any considerable volume of water, and the business-like Chinese owner seems to be quite keen to try the foreign machines, where Chinese labour, plentiful and cheap, has failed. With easily accessible coal-fields in the past, the Chinese had no absolute need for machinery, and in a labour-producing country they viewed labour-saving machines as inventions of the devil. But many of their fine mineral-fields need machinery and a practical demonstration of what steam and electricity can do will make a very strong and favourable impression on the Chinaman's mind, and shew him that he must either be left behind in the race, or touch up his old civilization with the more progressive brush of the West.

As the people of Northern Honan were rather unfriendly in June, 1900, and as troublous events were happening in the north, a full investigation of the Honan coal-field had to be deferred. Unfortunately, it was not considered advisable to attempt to cross the frontier into the province of Shansi, at that time, and the expedition had to move southward to Hankow, a 24 days' journey under very trying conditions.

### Shansi Coal-field.

The coal and iron from the Shansi plateau were, however, much in evidence in Honan, being carried by coolies down the mountain-passes; and the writer observed the excellence of the quality of the coal, and the fine condition in which it reached the plain. The Shansi coal-field is much easier to work than that of

Honan. It is estimated that the deposits are so immense, that they could supply the world's demand for fuel at the present rate of consumption for the next 2,000 years; and it will be interesting to note the effect of placing this vast coal-field in railway-communication with the sea and the markets of the world. Its present isolation and the want of facilities for inter-communication throughout China make it only necessary to scratch it for local uses, but it is hoped that at an early date British engineers will develop those vast mineral resources and give that part of China the facilities for inter-communication that is of such vital importance.

In working the seam, about 22 feet thick, the want of timber is overcome in a very ingenious way. The block of coal that is to be removed is cut round, as is usual in working thick seams. The lower portion of the seam is honeycombed under this block, with narrow drivings, just sufficient division-walls being left to render the places safe while being driven, and yet just sufficient strength to give way under the weight of the coal above. The miners by experience know when to expect the overlying coal to fall, and they fill it away in the usual manner, leaving an open gallery surrounded by solid pillars of coal. The Chinese, in mining, as in all their undertakings, have frequently a long way to go in carrying out their plan, but they are invariably successful at the finish.

## Province of Sze Chuen.

After a time of enforced inaction in Shanghai, it was the writer's privilege to visit the province of Sze Chuen, the richest of the eighteen provinces of China. It was a journey of 1,000 miles up the river Yangtze, to the treaty port of Ichang, by steamer, and thereafter by house-boat, a month's journey through the famous Yangtze gorges to the treaty port of Chungking. The scenery passed through in the journey from Ichang to Chungking surpasses description, the conditions are ever varying and always full of interest, whether it be in the passage of the deep rock-bound gorges or over the dangerous and difficult rapids.

The coal-measures of the province of Sze Chuen are the most extensive in the world. Underlying the red sandstone and marls of the enormous red basin is one vast coal-field; and where the strata have been tilted to form anticlines with limestone-cores, and intersected by transverse gorges or water-ways, there the coal-

seams are laid bare and are workable by adits. On both flanks of those anticlines the coal-seams are worked, and the writer has seen them worked in seams varying from 18 inches to 10 feet thick.

In the passage of the river from Ichang to Chungking, the writer visited several mines close to the river and was surprised at the better system of securing the mines and of ventilating them, in comparison with that adopted in the mines that he visited in Honan. The timbering was efficient, and carried out by methods that ensured a maximum of safety to the miner and placed him very high in the standard of practical men. The coals here seen were anthracitic and bituminous and in some cases high in ash and sulphur.

FIG. 2.—ENTRANCE TO A COAL-MINE IN SZE CHUEN, SHEWING WEIGHING-MACHINE.

In the neighbourhood of the city of Chungking, there are several exposed coal-fields and in the examination of one of them the writer had a rather novel experience. The manager of the mine stated that a coal-hauler entered the mine at 8 a.m. with his empty trolley and emerged therefrom at 2 a.m. on the following day, bringing out one load of about 10 cwt. of coal as his day's work. This statement, coupled with a vaguely expressed estimate as to the length of the principal adit, induced the writer to make a survey of this particular mine, with the result that he found the main haulage-road to be 4 British miles in length. The seam was

thin (about 2 feet thick), and the coal of a quality equal to Welsh smokeless coal, and was worked in a longwall, most creditably arranged.

The main haulage-road was divided into eleven lengths, divided off by separation-doors. The seam dipped about 1 in 10, and a space between the upper pack-wall and the coal, left for the neighbouring mine to follow on with in their working, formed the return air-way. There must have been an air-space, as even at a distance of 4 miles in-bye the ventilation was good and the mine quite cool, but as none of the present generation of miners had been through the air-way the writer considered it

FIG. 3.—ENTRANCE TO A COAL-MINE IN SZE CHUEN, SHEWING TIMBERING AND A MINER DRAWING A COAL-TROLLEY UP AN INCLINE OF 1 IN 5.

advisable not to attempt to survey it. The friction of the air was overcome by giving it a push forward, as it were, by the aid of a hand-fan, 8 feet in diameter, placed at each of the separation-doors, delivering their air through square boxes carried just beyond the separation-door.

The pack-walls in the mine were well built, and the working-places efficiently propped. The roof of black shale was blasted to give head-room and the road-way averaged 5 feet in width by 4½ feet in height. The rails were simply angles of wood; and the bamboo trolleys, built on a wooden frame, had wooden wheels, hooped with iron, and iron spindles. The roadway was kept dry

by the water being carefully led into proper channels at the sides. In crossing a fault, the roadway dipped 1 in 7 for a distance of about 300 feet in three places in the mine, and it was in dragging the trolleys up these inclines that most time was lost to the hauler. The coal-face was about 1,200 feet in length, and the particular mine surveyed had other seams working both above and below it.

Naked lights were used—clay-lamps burning an inferior vegetable oil. The lamps had bamboo handles attached, and this unwieldy appliance is carried by being inserted in the twists of the pig-tail, which is wound round the head during working hours.

The miners were cheery, well-built fellows, and talked and looked very superciliously at the "foreign barbarian" visiting them in their mines. They were most attentive, however, and the miner who wheeled the writer out of the mine on the return journey was exuberantly grateful on the receipt of copper cash to the value of 2d. Hot baths are provided free of charge by the mine-owners for their workmen, who are very cleanly in their habits.

Blasting is effected by Chinese gunpowder, but fortunately the writer was spared the odours of that compound, else he might not have been able to report so favourably on the ventilation of the mine.

The survey of this particular mine, or some anti-foreign feeling amongst the people, led to the inconvenience of the writer being shut up in a temple in which the party was accommodated, for a period of 3 days, during which time the British Consul at Chungking arranged successfully for his release and for his further safety and conduct.

Other mines in this neighbourhood, also entered by adits, were working seams dipping 80 degrees and of thicknesses up to 10 feet. Here again, the timbering was splendidly done. The haulage-roads had steps between the rails to give a foothold to the poor fellows who had to drag the coal from the dip-workings. Fortunately for them the presence of water restricts operations, and foreign machinery is absolutely essential to the life of most of these mines, where most of the upper coal-seams are worked out.

The writer was confirmed in his opinion of the thoroughness of the system of timbering adopted in this district by the inspection of one mine that had been abandoned on account of water for fifteen years, and was first opened out over 90 years ago. The

mine was entered by a tunnel, 7½ feet high, 5½ feet wide, and upwards of a mile long. The roof was arched and the whole of the tunnel, driven mostly in sandstone and limestone, was chisel-dressed. The tunnel was absolutely straight from start to finish, and in the workings the old disused haulage-roads were as clean as if in daily use. The timbering was intact, the props and bars in line as if they had been laid there but recently, and under the superintendence of a keen mathematical surveyor. A communication to the surface to the rise of the high pitching measures showed a strong current of air produced by natural ventilation.

A further journey to the west, up the Yangtze to the city of Lu Chou, and thence an ascent for 100 miles of the Tô Kiang a tributary of the Yangtze, gave opportunities for a further view of the Sze Chuen coal-fields. As before, the mines were worked where an upheaval of the strata had rendered the coal-seams easy of access.

### Brine and Petroleum.

From the city of Fushun, the famous brine- and petroleum-wells of Tsz-Liu-Ching were reached. From a mining point of view this district is most interesting, while from the Chinese point of view it is extremely valuable, as the brine-wells contribute an enormous revenue to the Chinese Government. The first glance at the brine district gives one the impression that a British mining district is being entered. Studded over an area of about 30 square miles are some 5,000 head-gears, and the whole region is a hive of activity and life. The Chinese are perhaps the pioneers of boring operations. At all events, their results from their own initiative are truly marvellous. Conceive boring-rods made of bamboo, a heavy iron borehead, casing for running-ground made of bamboo strips fastened together, tools for recovery of rods mostly made of bamboo, a bamboo sludge-pump and a built bamboo head-frame with a motion communicated by a simple bamboo lever, and you have before you all the apparently impossible success of Chinese boring. Contrast their plant with a modern diamond-drilling plant which is thought to do good work if it puts a hole down successfully for a distance of 2,000 feet, but does remarkably good work if it reaches 3,000 feet. And yet the Chinese even exceed a depth of 3,000 feet with their primitive appliances. Of

course time is no object to them, and a hole of this depth frequently takes 10 years to complete.

The brine and oil are raised by bamboo sludge-pumps about 70 feet long, attached to a bamboo-rope, which is wound on a vertical winding-drum, about 21 feet in diameter, worked by 3 bullocks attached to the outer edges of the drum. The pump is lowered by a loose drum. About 50 per cent. of the brine leaks away from the pump on the upward journey, but to the Chinese that is a mere detail. In conveying the brine from the wells, bamboo pipes about 4 inches in internal diameter are used. The pipes are bound round with fine bamboo threads to keep them water-tight. Bends are not used, but the pipes are let into junction-barrels to allow of a change of direction. Where it is necessary to convey the brine over a hill to the evaporation-station, a series of pumps are used, and the pumps are worked like a tread-mill by an army of men. The lift of a pump is generally about 10 feet vertical, and as the pumps are simply chain-pumps on which at close intervals wooden vanes are fixed, an enormous amount of labour is wasted. In this particular brine district, the writer estimated that 10,000 men were employed in the conveyance of brine and salt, where one well-constructed foreign pump and a couple of Lancashire boilers would easily and more efficiently do the work. On mentioning this to the official who escorted the party over the district, he expressed every admiration for the work of the pump, but said "What am I to do with my 10,000 men, if I adopt such an appliance?"

The brine is evaporated in cast-iron pans about 3 feet in diameter and 9 inches deep, either over coal-fires or, in the case of wells where natural gas is given off, the gas is conveyed in bamboo, clay-covered pipes under the evaporating pans, and ignited. Wells that give off natural gas in any large volume are generally capped, and used only for their value as gas-wells.

The petroleum-deposits are associated with the brine, and the oil is recovered by skimming the surface, when the brine is settling in the brine-reservoirs.

In the Tsz-Liu-Ching oil and brine districts, it will only be a matter of time till the Chinese appreciate the value of and adopt foreign machinery.

A descent of the Yangtze river, in flood, gave an altogether different impression from the ascent at low water.

## Shantung.

Following upon the journeys through Sze Chuen, where various other minerals were also inspected, the writer visited the gold-mines of north-eastern Shantung. One of the quartz-reefs, 40 feet wide, between walls of granite, and with a dip of about 75 degrees, was worked in a most interesting manner, and practically without the use of timber, which was too expensive at that particular place, on account of the old complaint—want of facilities of inter-communication. Galleries were opened on the reef, in some cases 40 feet high, 100 feet long and the full width (40 feet) of the reef. Small pillars of ore were left to support the walls, and the limit of safety is so well defined as the result of experience that accidents are rare. The quartz is conveyed to the surface on trolleys, broken and sorted, carried by coolies in baskets to the mill, a distance of about ½ mile down hill, further broken by hand, dry-crushed to powder by mule-driven granite-rolls, washed, and the gold recovered on square buddles or over copper-plates.

The tailings are worked over twice by the owner of the mine, and thereafter several families make a livelihood by further washings. In alluvial-gold washing the Chinese is second to none. He has a maximum of patience and requires a minimum of remuneration. On the Yangtze, the Han, and other rivers, thousands of Chinese wash the sands and gravels for gold, at low-water, and with their basket-cradle and simple table recover on an average enough of the precious metal to pay them from 3d. to 6d. per day.

## Modern Chinese Mining.

A visit to the works of the China Engineering and Mining Company, through the courtesy of Mr. Houva, chief engineer, formed a pleasant termination for the time to the writer's inspection of Chinese mines. The properties of the company are situated midway between Tongku, the port of Tientsin, and the harbour of Ching-Wang-Tao, at present under construction. There are seventeen coal-seams. The collieries are laid down with modern machinery and modern pumping-plant. The Chinese under foreign supervision work these collieries successfully, and what has been achieved at these mines by the adoption of foreign methods and machinery can be achieved throughout China. The writer himself hopes to become a factor in that work, and at a

future date, as the result of extended knowledge of the country, he will perhaps be able to communicate to The Institution of Mining Engineers more detailed information than his recent hurried travels in the immense empire of China have permitted.

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Mr. J. R. R. Wilson proposed a vote of thanks to Mr. Reid for his paper.

Mr. W. E. Garforth seconded the resolution, which was cordially approved.

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## DISCUSSION OF MR. W. E. GARFORTH'S PAPER ON AN "EXPERIMENTAL GALLERY FOR TESTING LIFE-SAVING APPARATUS."*

Mr. W. E. Garforth said that he had on several occasions tested a new apparatus, which had a great advantage over the apparatus tested in September last, inasmuch as the explorer was not required to regulate the supply of oxygen, which was automatic. He had suggested that the apparatus was very fatiguing when the heat became great, and that it might be possible to cool the apparatus; and this had been effected by means of compressed carbonic acid. The apparatus was now much more comfortable, owing to the automatic regulation of the oxygen-supply and the cooling arrangement; but on the other hand it was scarcely as convenient as the pneumataphore and Meyer helmet.

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## DISCUSSION OF MR. W. N. DREW'S DESCRIPTION OF "AN INSTRUMENT FOR THE AUTOMATIC RECORD OF WINDING-OPERATIONS."†

Mr. M. H. Habershon, producing some of the paper-bands which had been taken off the instrument working at the Tankersley colliery, said that each of the bands shewed the record of a day's winding:—Each draw was indicated by a dot, and the number of waits and their duration, both at the bottom and the top were shown, together with every time that the shaft was used for the

* *Trans. Inst. M.E.*, 1901, vol. xxii., pages 169 and 192.

† *Trans. Inst. M. E.*, 1901, vol. xxii., page 42.

purpose of drawing or lowering men. The paper band moved at the rate of about ½ inch in five minutes. Each wait at the pit-bottom was shewn by a blank space, and waits at the pit-top were indicated by straight lines. In the case of a double-decked or three-decked cage, it would be necessary to arrange for the paper-band to travel at a greater speed. The apparatus could be fixed in the office of the manager or time-keeper, and would form a check on the entire drawing-operations.

Mr. W. DURANT stated that the apparatus was in working order at the Tankersley No. 2 pit, and the paper-band was placed in the manager's hands every morning as an automatic record of the work of the winding-engine on the previous day.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## GENERAL MEETING,
HELD AT HANLEY, JANUARY 13TH, 1902.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBERS—

Mr. J. R. HEATH, Engineer, British Gas-light Company, Limited.

Mr. F. W. PAUL, General Manager, Shelton Iron, Steel and Coal Company, Limited.

ASSOCIATES—

Mr. WM. CHESWORTH, Mechanical Engineer, Birchenwood Colliery.

Mr. F. GERRARD, Under-manager, Silverdale Colliery.

Mr. H. HODSON, Assistant Engineer, Parkhall Colliery.

Mr. C. PEARSON, Mechanical Engineer, Whitfield Colliery.

Mr. A. SPROSON, Under-manager, Florence Colliery, Longton.

STUDENTS—

Mr. C. NEWTON, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.

Mr. V. F. WITHEY, Surveyor, Florence Colliery, Longton.

Mr. A. H. STEELE, Mining Student, Wheatley Place, Bucknall Road, Hanley.

Mr. H. S. POOLE's paper on "The Coal-fields of New Brunswick, Canada," was read as follows:—

# THE COAL-FIELDS OF NEW BRUNSWICK, CANADA.*

By HENRY S. POOLE, F.R.S.C., F.G.S., etc.

## Introduction.

The earliest maps which outlined the geological features of the Maritime Provinces, coloured a large area of New Brunswick and Nova Scotia as Carboniferous, and the Acadian coal-fields were spoken of as covering 18,000 square miles, of which two-thirds were given to New Brunswick.

From the miner's point of view, this mileage must be largely curtailed, great blocks of country being occupied by lower measures totally barren of coal, and other sections disclose only very thin and quite unworkable seams. The Carboniferous formation connects both provinces, but in Nova Scotia alone are found seams exceeding 4 feet in thickness. It is only in small areas in New Brunswick that a seam is known to reach a thickness of 30 inches. The conditions of deposition are dissimilar in the two provinces; the strata of New Brunswick are practically flat, those of Nova Scotia inclined and leading to great depths. While the coal-trade of the latter has of late years rapidly advanced, that of the former remains stationary and in the hands of workmen operating without capital or appliances of the simplest kind, without steam or railway connection. Associated with these thin seams are shales and sandstone-beds coloured dark-red by iron, and they are unaccompanied by strata rich in bituminous matter such as are met with in the Coal-measures of the sister province.

The presence of coal was discovered by early settlers, and from time to time explorations have been made in search of thicker seams both with and without aid from the provincial government. The present increased demand for coal and the greatly enhanced price have again stimulated prospectors, and suggested a re-examination of the field, of a more detailed nature than was possible when the first general survey was made by the officers of the Geological Survey of Canada a quarter of a century ago.

* Plate II.

The horizontality of the beds, the coast-line generally low with its covering of sand, and the superficial deposits of drift, leave but few natural exposures over much of the country. To supplement these, bore-holes have been sunk, and valuable information has been thus obtained; but the selection of the sites for the bore-holes was determined by the interests of the explorers, and the search by this method was not conducted on any general system for proving the coal-formation as a whole. Whether the horizon of the thick coal-seams of Nova Scotia has its representatives, and if it has, whether the beds also contain workable seams in New Brunswick, are questions which are still open to discussion.

### Position of the Coal-formation.

The rocks of this series lie south of Baie des Chaleurs, in an area roughly triangular, and widening to the southwest they abut on the coastal range of old rocks that border the Bay of Fundy. Then, overlapping these old rocks at the eastern end of the range, they fold round and connect with the lower members of the Nova Scotian field. Dipping at a slight inclination to the eastward with some four gentle undulations parallel to the coastal range of hills, they are overlain by newer formations that skirt the Northumberland Strait and compose the contiguous Prince Edward Island. The western limits rest on the highlands of Cambrian and Silurian strata, that extend for about 160 miles from Bathurst on Baie des Chaleurs to Oromocto Lake in the southwestern corner of the province.

The great mass of the series consists of grey sandstones, while the higher members on the Gulf of St. Lawrence and Northumberland Strait are brownish-red, the lower members are chiefly bright red. Apparently, all are conformable and no decided break has been detected separating the red from the grey series, although to the eastward in Nova Scotia an unconformity at this point is invariably found. There are, however, reasons for suspecting that breaks in the sequence may exist, but are obscured by the prevalence of false bedding in the horizontal strata. Between the two series, at several exposures on the western margin, occur igneous intrusions, and apparently only at the one horizon where the bright red series ends and the grey series begins.

Sections in detail of the strata seen at these exposures would, it is believed, also show a marked thinning of the measures to the

westward, as compared with what is to be seen to the south-east at the head of the Bay of Fundy, where the formation is most fully developed and exposed in one continuous sequence. Here Sir William Logan, in 1843, measured and made famous the Joggins section of 14,571 feet without a break in the series exposed in the cliffs. This section begins with the Carboniferous Limestone series, includes the gypsum beds, the bright-red measures under the grey Millstone Grit, the Coal-measures proper, and the barren Upper Carboniferous or Lower Permian. The equivalent horizon of the latter, the highest in the section, is a matter of dispute, but the tendency of to-day is to class it as Permo-Carboniferous. Its relation in the series is of importance in this enquiry, and whereas in other parts of the field the sequence is imperfect, intermediate strata being absent, the Permian rests unconformably on Millstone Grit beds.

As no exposures are known of strata believed to be equivalent to the Nova Scotian Coal-measures, no series of that age merely hidden by superficial drift, there are no inducements for closer examination of one portion of the field more than another, and a study of the formation as a whole seems essential to further investigation and the establishment of the true relation of the exposed strata with those sought for. In such investigation, the coal-field of New Brunswick may be conveniently divided into two districts by an east-and-west line running through Indian Mountain and parallel to the general course of the railway from Moncton to St. John and the Kenebecasis river. The district north of this line would include the present working coal-field on the Grand Lake—to be elsewhere spoken of—and all the flat country on the north and east. The southern district would then embrace the more highly inclined and disturbed country bordering on Nova Scotia and connecting with her Cumberland coal-field.

North of Bathurst on the Baie des Chaleurs and outside the limits of the continuous coal-bearing rocks, the bay has in places a fringe of the lower red rocks, originally distinguished as the Bonaventure formation, but here the grey overlying series is absent. This portion of the bay is, however, not without its coal, and at Dalhousie, among the igneous rocks that have altered some of the Upper Silurian fossiliferous beds of Inch Arran, there appears an irregular bed of bituminous shale, including a few inches of coarse coal and light grey under-clay. These bituminous

beds lie between beds of tuff, and are coarsely crumpled, dipping with the igneous deposits at a high angle to the northward into the waters of the bay. The shales enclose plant-remains which are obscure, and nothing has been discovered there to show their age, whether Devonian (with the interesting fish-bearing beds of the neighbourhood at New Campbellton and Scaumenac Bay), or Bonaventure, or possibly Millstone Grit. On account of their igneous associates, the latter supposition seems the least likely, and without parallel in the red series of the neighbourhood: thus the probability seems to point to their being Devonian. They are exposed along the beach, where the undulations bring them into view for over a mile in length.

The red Bonaventure formation underlies Bathurst and rests on the lower rocks, Silurian and Devonian, and the granite of the Nipisiguit river. It continues as a narrow belt to the south-west on the confines of the Carboniferous, and is infrequently concealed by an overlapping of the grey series.

East of Bathurst, on the southern shore of the Baie des Chaleurs some 400 feet of grey strata have a gentle dip towards the Gulf of St. Lawrence, and at Clifton contain three small seams of inferior coal, 6 to 8 inches thick, associated with dark-red beds partly calcareous, and sandstones quarried for the use of tool-makers and marble-workers, for pulp-mills, for snaiths and grind-stones, each use calling for a special quality of grit, size of grain, and hardness, distinguished by the skilled quarrymen of this shore.

Outcrops of similar seams equally valueless have been noted at Caraquette and Pokemouche, and reported at Shippegan. The relation of these seams to those next observed on the southern shore of the Miramichi river has not been determined, nor has the source of waterworn coal-pebbles in arenaceous beds at Indiantown been discovered. Indications of coal, fragments in the soil, have been reported elsewhere, and thin seams on the rivers Dungarvon and Miramichi near Doaktown.

Exposures of coal have been made in road-drains, others have been laid bare by the tides on the fore-shore and sea-cliffs; landslips have brought some into view, and from the bed of streams the lumberman's rafts of logs propelled by the current have brought away samples, but in every case the seams so far discovered have been thin and the quality generally questionable.

At the present time, working is conducted in three localities

only—Grand Lake, Coal Branch, near Harcourt, and Dunsinane, chiefly at the first-named. At Coal Branch, operations are carried on in the winter by drifts from the river-bank to such a depth as the ventilation allows, or the fear of falls permits the digger to proceed—at the best but a short distance, 100 feet or so. Then a new opening is made. The places are driven 8 feet wide, with a narrow roadway between timbers in the centre, and as the seam is only from 12 to 17 inches thick, much waste has to be removed, and most of it is brought outside.

In this neighbourhood, explorers this year reported the finding by bore-hole of a 5 feet seam, and sustained by this report they have been sinking a shaft, 20 feet long by 12 feet wide, to win the expected coal at a depth of some 130 feet. Approval has been generally accorded the operators for their faith in the find, experience hitherto in the province in no case outside the district of Grand Lake meeting with an approach to this thickness.

## Grand Lake.

The body of water known as Grand Lake, 25 miles long, in the centre of the province, is shallow and with a surface below the level of high-water in the Bay of Fundy. The ebb and flow of the tide but slightly affects the St. John river, controlled as they are at the mouth of the river by a rocky bar which produces an unusual phenomenon, a semi-daily reversal of a water-fall. Beginning with slack-water, when navigation is possible for a couple of hours, the outward flow through the narrow gorge at the entrance of the river increases, and as the tide falls develops a rushing, swirling torrent and cascades; low-water is followed by a reversal of intensity in the flow, slack-water is again reached, navigation resumed, and is followed in due course again by the growth of the water-fall, but this time the flow is in the opposite direction, and the fall takes place inward from the sea towards the head of the river. A repetition of the action is succeeded by a normal outward flow of the river.

The Grand Lake coal-field lies along the northern shore of the lake and is intersected by the Newcastle river. It has an area of about 100 square miles, and hitherto has yielded from 6,000 to 10,000 tons a year. The land-owners do the mining, each in his own holding, carting the coal to a wharf, where it is stacked for shipment by lake and river to St. John and Fredericton, the

chief towns of the province. Increased shipping facilities will be available on the extension of the Harvey and Chipman railway to Fredericton, as it will pass through the coal-field; and in all probability it will be built next year.

There is but one seam worked. It has a thickness generally of 22 inches, with local area thickening to 3 feet, when an extra bed develops either above or below the main band and a dividing layer of fire-clay. This seam lies close to the surface, which approximately coincides with the seam's gentle undulations. A cover of 60 feet is considered to be the extreme, a few feet being more usual, while the small water-courses have in part denuded away both the cover and coal. Open-cast stripping is practised where the soil lies thinly over the coal, elsewhere the mining is all narrow work, and it is seldom that so many as 6 men share in the operation.

About the head of the lake, the seam is somewhat thinner, and farther eastward on the Salmon river still more so. On continuing in the same direction, the district of Coal Branch is reached on the farther side of the Intercolonial railway running northward to Quebec, and reference has already been made to this mining centre. An opposite course to the westward traverses a large area of grey rocks in which no more than a few inches of coal have been discovered. It would seem as though the strata here are all lower than those at Grand Lake, and a 600 feet bore-hole, at a point 18 miles south of Fredericton, found chiefly purple sandstones without any coal.

At Grand Lake, the working seam being so close to the surface and the beds lying so flat, whatever might be below is concealed: search has here also been made by bore-holes. The first hole, put down by a diamond drill in 1872, passed through the surface-seam, but failed to find any other seam within a depth of 170 feet. The second hole, starting at a lower horizon, pierced coarse grey grit and conglomerate at 211 feet, resting on Devonian slates, and without other coal-seams. The Devonian slates, which here show the basin to be shallow, come actually to the surface a few miles off to the northeast, and again on Canaan river some 8 miles within the limit of the northernmost of the two districts, into which for convenience the provincial coal-fields have been divided.

In the southern district, a limited coal-field has been explored

at Dunsinane by pit and bore-hole. It contains one seam of 22 inches that yields 17 inches of clean coal. The record of a bore-hole, ½ mile away, gave 40 inches of coal, but this has not yet been confirmed by a pit-exposure. Nowhere else in this section of country are seams of equal thickness to be seen, and 1,000 feet of barren grey beds have been proved to underlie.

These beds thin as the land falls off to the eastward, and down the Petitcodiac river the contact of the red and grey series is frequently observed. Still farther east, close to Moncton, the "Crewe" station of the Intercolonial railway-system, an inferior seam appears, also less than 8 inches thick. Possibly it is the same bed that is seen at Cocagne, Aboushagon, and other streams in the upper beds of the series near the Permian on the coast. Here comes in the debatable ground—viewed as an ascending series, the strata appear to be a continuation of the Millstone Grit; examined from the east from the Permian downwards in a descending series, the absence of a marked change and no unconformity being apparent, a much higher horizon is suggested. In the adjoining Nova Scotian county of Cumberland, explorations lately conducted by Mr. Hugh Fletcher* of the Canadian Geological Survey, show strata somewhat similar, with dark-red bed associates overlying the measures that contain the numerous and thick seams of the Spring Hill coal-field. The horizon may yet be shown to be the same as that under review in New Brunswick, and yet be unaccompanied by the much to be desired and much sought for thick coal-seams of Nova Scotia.

The general structure of the nearest working coal-field, that of Cumberland, is not without interest to this enquiry. In form it is triangular, with its base to the north, bearing the Joggins seams. These thin to the eastward, and then beyond a break in the sequences, in the easternmost corner, lies the more valuable Springhill coal-field. In the opposite direction, the Coal-measures extend under the shallow waters of Cumberland Basin and Shepody Bay to the New Brunswick coast, where the measures of the Millstone Grit still remaining at Cape Maringouin, Grindstone Island and Mary Point at an angle of 50 degrees are tilted to 60 degrees and ultimately to 75 degrees, as they are deflected from the westerly course to run down the coast and

* "Summary Report on the Operations of the Geological Survey, 1899," *Annual Report of the Geological Survey of Canada*, 1899, vol. xii., section A.

65°
64°30'
64°
48°
47°30'
47°
46°30'
46°
45°30
45°
CHALEURS
Caraquette Bay
SHIPPEGAN I.D.
SHIPPEGAN
CLIFTON
GULF
OF
ST LAWRENCE
Miramichi Bay
PRINCE EDWARD IS.
NORTHUMBERLAND STRAIT
PALMERSTON
COAL BRANCH
COCAGNE
Cocagne Head
Cape Jourimain
WESTMORLAND
MONCTON
PORT ELGIN
Baie Verte
ALBERT
HARVEY JUN.
SPRINGHILL JUNC
SPRINGHILL MINES
JOGGINS
CUMBERLAND
PARRSBOROUGH
Mines Basin
Mines Channel
KINGS
DOMINION ATLANTIC RAILWAY
NOVA SCOTIA
ANNAPOLIS
65°
64°30
64°

parallel the hill-range to Cape Enragé into the open Bay of Fundy. The overlying beds of the section will follow this turn and place the outcrop of the coal-seams under the water of Shepody Bay.

From the eastern angle of the basin at Springhill, the Carboniferous-measures lie on the northern flanks of the Cobequid Hills of Devonian age. This range parallels the series of anticlines in the gold-bearing Lower Cambrian rocks of the Atlantic coast, and to the westward leaves but a small opening into the Bay of Fundy, beyond an extension of the measures at Cape Enragé. Has this area, it may be asked, at one time been a separate basin; or is it but a depression remaining of one vast coal-field lying to the north of Nova Scotia, under the Gulf of St. Lawrence, of which it and the other detached coal-fields of Pictou, Port Hood, Broad Cove and Chimney Corner, etc., are outliers? Is it continued to the north beyond the foldings that bring to the surface the limestone-and-gypsum series that forms its base?

### Albertite.

New Brunswick had a coal-mine of great value in the latter half of the last century, a vein of albertite in Devonian shales rich in bitumen at the eastern end of the coastal range. This material at one time sold at as high a price as £4 10s. (22 dollars) a ton, and much money was spent in search of other veins of workable size, without success. The shales are full of fish-remains, and so rich are some of them in bituminous matter that it has been proposed to put them on the market as a fuel, but the attempt has yet to be made.

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The President said that the paper, as a geological record, was of great interest, but it did not appear that the coal-field was a rich one. The seams that had been worked appeared to be very thin, although thicker seams were said to have been proved by borings. He proposed a vote of thanks to Mr. Poole for his paper.

Mr. A. M. Henshaw seconded the motion, which was carried unanimously.

## DISCUSSION OF MR. PERCY TURNER'S PAPER ON "COAL-MINING AT DEPTHS EXCEEDING 3,000 FEET."*

The PRESIDENT (Mr. W. N. Atkinson) remarked that there was one point, which perhaps would be the most important—the increase of temperature at great depths. A few days ago, he took a rock-temperature at the Sneyd sinking, at a depth of 2,400 feet, of 85¼° Fahr., which was a rate of increase of about 1° Fahr. for 67 feet. The rate of increase varied considerably in different localities, but this observation appeared to show that it was not above the average in North Staffordshire.

Mr. E. B. WAIN remarked that the determining factor in working deep mines must be the temperature, in which the men could economically work. There was no doubt that, whatever appliances might be adopted for facilitating the removal of material, the labour-question would become very serious in deep mines; in fact with improved appliances for coal-cutting such as were coming to the front, it might prove more economical to work some of the thinner seams which were now being left unworked at shallow depths rather than the thicker seams at great depths. He could not agree with Mr. Turner that the conditions at depths of 2,000 and 3,000 feet would probably be such as to render packing impracticable.† His experience only extended to 2,000 feet, but he must say that it pointed to a different conclusion from that arrived at by Mr. Turner—that roofing that would stand well in narrow roads 1,000 feet deep would not stand nearly so well at double the depth, and that the deeper the workings extended the more necessity there would be to take out the whole material and work on packed roads. In the Cockshead seam, particularly, which had one of the finest roofs of the North Staffordshire coalfield that had ever been worked, in the case of workings about 2,000 feet below the surface, it was found necessary to take out the whole of the seam and build in packwalls. The subsidence was more apparent at that depth than at a considerably less depth, and the pack-walled roads stood very well.

The PRESIDENT (Mr. W. N. Atkinson) said that he was inclined to agree with Mr. Wain in the latter part of his remarks, with

* *Trans. Inst. M.E.*, 1901, vol. xxi., page 61. † *Ibid.*, page 66.

regard to the effect of pressure on the roof and roadways in deep mines. As a general rule, below a limited depth, it appeared that the deeper they went the weaker became the strata. He could not state that any particular roof had deteriorated from a moderate to a great depth; but his general impression was that as a rule the strata were more tender at great depths than at moderate depths, and further that the removal of the whole seam and working on pack-walls was more beneficial at great than at shallow depths.

Mr. A. M. HENSHAW said that he had some knowledge of a colliery in another district where coal-seams were worked to depths of 3,000 feet lying at an angle of 30 degrees; the working-faces were about 4,000 feet from the pit-bottom, and no more difficulty in maintaining pack-walls appeared to be experienced at 3,000 feet than at 1,000 feet, although the same method was adopted. One seam was 4 feet 6 inches thick, another was 2 feet thick, and another, with a total thickness of about 10 feet, with alternate layers of coal and shale, was worked very successfully by the long-wall system, at a depth of 3,000 feet, in fact as much so as at the shallower depth. He had not measured the temperature, but a recent inspection led him to the conclusion that the temperature of the thinner seam was lower than that of the thicker seam. He suggested that the increase of temperature might not altogether be due to the thickness of the seam, but to the extent of surface exposed to oxidation.

Mr. J. T. STOBBS remarked that the most important question as to temperature in deep mining was, not its effect on labour, but its effect in producing an absorption of oxygen, a difficulty which would have to be overcome.

Mr. JOHN GREGORY asked whether at the depth of 3,000 feet there were any roadways in solid coal in addition to those between pack-walls. If so, it would afford an interesting comparison as to the merits of both systems at so great a depth.

Mr. A. M. HENSHAW replied that the seams were worked by longwall.

Mr. E. B. WAIN stated that, in a seam where headings usually stood for 10 or 12 years at a depth of 1,200 feet, where it was

possible to leave the top coal, it was impossible at a depth of 2,100 feet to keep a heading without heavy timbering.

Mr. C. NEATE remarked that, in his experience, it was impracticable to drive headings in deep workings in the Cockshead seam. The temperature of the Seven-feet seam was 80°, while in the Ten-feet seam it was not more than 65° Fahr.

Mr. A. HASSAM was of opinion that in thick seams gob-fires would become more prevalent as the mines were worked at greater depths.

Mr. J. C. CADMAN said that in discussing the maintenance of the roof, the inclination of the seam should not be overlooked; and the various methods of making roads should be applied to the appropriate system of working.

The further discussion was adjourned.

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## DISCUSSION OF MR. JOHN CADMAN'S PAPER ON "THE OCCURRENCE, MODE OF WORKING, AND TREATMENT OF THE IRONSTONES FOUND IN THE NORTH STAFFORDSHIRE COAL-FIELD."*

Mr. WILLIAM STATHAM said that the commercial value of the mines varied in different districts. At Silverdale, the Red Shagg mine was most valuable; and at Chatterley, the Red mine was most valuable. Pincracks were a source of very great anxiety to colliery managers, and accidents, occasionally, resulted from them. In several accidents, through pincracks, the working-face had been weighting and a bump occurred, breaking the timber, and causing personal injury. The pincracks ran in connection with the main joints, and also the end or cross-joints, and not only in the measures, but where grit formed the roof they ran into the grit likewise. The order of extracting the seams must vary in different districts, as the distance between the seams varied in different places. At the colliery where he was engaged they had tried with great success the following order:—First, the upper seam, or Blackband; then the lower seam, or Red mine; leaving the Red

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 89.

Shagg mine, the middle seam, to be worked last. They considered that, by working the lower seam before the upper seam, they extracted the water from the floor, which was always troublesome in the Red Shagg seam. He could not advise this order of working in the Silverdale district, where it had been tried with disappointing results. The yardage in this system cost on an average ½d. per ton: namely, the Blackband seam, 0·6d. per ton; Red Shagg mine, 0·4d. per ton. He had taken out the timber-cost for 12 years, and the cost had been 2d. per ton on raw stone for all timber used in airways and main roads, including £400 worth of steel girders. He (Mr. Statham) suggested that jig-dips should be spaced 240 feet apart, which allowed 120 feet of working-face on each side of the dip. Another advantage of this system was that the output could be easily increased. A mine was started from the shaft-pillars, the first week 200 tons was raised, the fourth week 1,000 tons, thirteenth week 1,640 tons, and in six months 1,800 tons a week, thus showing that the system recommended itself to mining-engineers as a means by which they could readily secure a large output. The writer had drawn a sketch of a return airway made part in the solid and part in the gob. He (Mr. Statham) found from experience that it was better to build 20 to 25 feet of pack-wall against the solid than to form a permanent way half solid and half pack-wall. The writer suggested that the width of the working-face should be 30 feet, but he preferred 36 feet. There were several causes which determined the settlement of the roof, namely, the thickness of the seam, the inclination of the seam, and the rate of progress of the working-face, and possibly the weather had something to do with it. After continuous rain, great damage had occurred in the Red Shagg seam, which had a marl floor, into which the water penetrated, and the whole mine became alive. He might add that 1,040,000 tons of raw stone and 80,000 tons of coal and slack had been raised without a fatal accident and with few serious accidents at the working-face, which he took to be a good recommendation of the system.

The further discussion was adjourned.

# THE MINING INSTITUTE OF SCOTLAND.

## GENERAL MEETING,

HELD IN THE CHRISTIAN INSTITUTE, GLASGOW, FEBRUARY 12TH, 1902.

MR. JAMES S. DIXON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected:—

MEMBERS—

Mr. RICHARD JOHN ALLAN, Murtega Minerals Company, Limited, Barrancos, Portugal.
Mr. DANIEL M. ARBUCKLE, Northfield Colliery, Prestonpans.
Mr. JAMES CLELAND, Scremerston Colliery, Northumberland.
Mr. GILBERT MORRISON, East Grange Cottage, Dunfermline.
Mr. JOHN WHITE, Raneegunge Coal Association, 4, Fairlie Place, Calcutta.

ASSOCIATE—

Mr. JOHN STARK, Chapel Colliery, Newmains.

Office-bearers for the Session 1902-1903 were nominated.

The discussions of Mr. JOHN M. CAIRNCROSS' paper on "The South Lesmahagow Coal-field," and of Mr. ROBERT BROOM's paper on "Unwatering and Fitting a Lanarkshire Colliery," were closed, after each of the authors had been awarded a vote of thanks.

## DISCUSSION OF MR. HUGH PEARSON'S PAPER ON "THE RAND CONGLOMERATES, TRANSVAAL."*

Mr. Robt. Thos. Moore (Glasgow) thought that the theory put forward by Mr. Pearson in his paper, that the gold was deposited from solution in the matrix surrounding the pebbles, was the generally accepted one. There were, however, some points which did not appear to be fully explained by that theory. In the banket-bed, which he (Mr. Moore) had seen, there were several angular pebbles which did not seem to have been water-worn. Then in some places, as in the Heidelberg district, he had seen the banket merging into the surrounding sandstone without any parting, and the gold ceased to be found in the sandstone when the pebbles stopped. There must have been a change of conditions in the gold-depositing solutions, for which it seemed to him somewhat difficult to account.

The President (Mr. J. S. Dixon) thought that Mr. Pearson's conclusions were very satisfactory. He attributed the formation of the conglomerates or banket-bed to the gradual depression of the surface, and to the fact that the beach was always receding from its original position. He drew an inference from the beach at Brighton, where a deposit of pebbles was now being laid down: every wave that came in rushed up the pebbles, and they made quite a noise rolling one over the other. Heavy rains and storms were not necessary to wash out the quartz, because the same process went on very extensively on the shores of the Mediterranean.

Mr. R. W. Dron (Glasgow) said that in the gold-fields of California, areas of several square miles were occasionally seen containing deposits, 20 to 40 feet thick, of white quartz-pebbles, occupying the sites of ancient river-channels. In that case, the hard quartz had remained and had been rounded into pebbles, while the softer material had been washed away by the river. Some of the quartz-pebbles were several feet in diameter. The gold occurred in the form of grains and nuggets, mostly in the lower stratum of the deposit, and in this respect it was different from the gold found in the Rand conglomerate. It was very difficult to formulate a theory to account for such a deposit as the Rand conglomerate, but he considered that Mr. Pearson's paper was a valuable contribution to the literature of the subject.

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 209.

Mr. R. T. Moore referred to the difference which existed between the gold in the banket-beds and that to be found in the Californian gravels indicated by Mr. Dron. The banket-gold was of fine quality and visible gold was rarely seen, while the other was coarse gold.

The President (Mr. J. S. Dixon) alluded to the occurrence of a bank of white quartz-pebbles in the neighbourhood of Strathblane, and this, he imagined, was the result of glacial action.

The discussion was then closed, the author being awarded a cordial vote of thanks.

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The Secretary then read the following paper on "What is the least possible Waste in Working Coal?":—

# WHAT IS THE LEAST POSSIBLE WASTE IN WORKING COAL?

By JAMES BARROWMAN.

In the report of the Royal Commission on Coal of 1871 there is a sub-report by a committee, on waste in working, which contains the following sentences*:—

From the evidence of witnesses, who were selected for their experience, as well as from our own knowledge, we have reason to believe that although in many instances waste in working is reduced to a minimum, while by the discovery of new uses for small coal the quantity left below ground or consumed in large heaps upon the surface is much lessened, and while generally a manifest improvement is being made in the working of coal, especially by the extension of the system of longwall, yet that coal is wasted by bad working and by carelessness, and that to a very considerable amount in proportion to that actually used.

The loss, we find, arises sometimes from ordinary circumstances, which are under the control of the colliery-owners and workers, and sometimes from extraordinary circumstances, which are under the control of others, or where the special peculiarities of the mine render the loss almost unavoidable.

At present, under favourable systems of working, the ordinary and unavoidable loss is about 10 per cent., whilst in a large number of instances, when the system of working practised is not suited to the peculiarities of the seams, the ordinary waste and loss amount to sometimes as much as 40 per cent.

The principal cause of this unavoidable waste arises from pillars being crushed.

In addition to this there is the following waste or loss which is variable, but sometimes very great, arising from the following causes:—

1. Much small coal is still either left belowground, or consumed in large heaps on the surface.

2. The requisite holing or undermining is frequently wastefully made in good coal.

3. The whole or part of a bed of coal adjoining or lying near to that which is being worked is left behind, where it becomes crushed and unworkable hereafter, because it is either of a kind that is not wanted at the time, or if it were worked the cost per ton of the coal got would be increased.

4. Properties which alone are too small to form a separate colliery, or a small part of a property severed by a large fault, and in consequence passed by during the working of the adjoining coal, so as ultimately to be crushed on the removal of the surrounding coal, or from the adjoining old workings becoming filled with water which it would not pay to pump, or by old pits by which it might have been worked being filled up.

* Vol. i., page 116.

5. Coal is left unworked through contention as to which of two or more owners should pump the joint water. Portions of seams situated to the dip are rendered unworkable in consequence of water being allowed to flow from other properties, when it might be run off either by free drainage or pumped at a shallow depth.

6. The whole of the coal in a colliery opened out in pillars is sometimes inundated by a considerable river-estuary or the sea breaking into the workings in consequence of the removal of pillars, or by incautiously working too near the surface. Large areas of coal must also subsequently be sacrificed as barriers against such inundated workings.

7. Barriers are left round small properties, or crooked boundaries, whereas if a barrier were properly laid out it would be more economical and afford the same if not more effectual protection.

8. Large tracts of coal of uncertain area are left as barriers, owing to there being no plans or records available to shew the extent of the old workings and explorations. Also portions or areas of coal-seams are not sufficiently proved to justify the expenditure for sinking pits when sufficient information might have been obtained had the records of previous explorations and copies of the sections of borings been preserved in an available form.

9. Strata yielding a continuous supply of water are pierced by shafts and bore-holes which are not protected by water-tight casing, or not carefully filled up and puddled when temporarily left off working or abandoned.

10. Main faults serving as natural barriers to keep back water are cut through, and the coal on the other side is thereby flooded.

11. In populous and manufacturing districts large areas of coal are left for the support of the surface and buildings.

It is not intended that any of the causes of loss enumerated above should be brought under review in this paper. The only loss which comes into effect in the following figures, bearing upon the working of coal in Lanarkshire, is that which sometimes, and chiefly in longwall workings, results from the presence of fire-clay holings or other foreign matter in the small coal of the working-faces, so deteriorating it as to cause its rejection by the miner, and that which is the consequence of failure to take out the last fragments of pillars in stoop-and-room working: but these only in so far as such loss is unintentional or unavoidable. For, though it is still customary in some collieries in Fifeshire and Ayrshire deliberately to throw back and to leave dross in the workings, this practice does not exist in Lanarkshire; and while it is recognized that in the extraction of pillars it is not always possible to take out the last shovelful of the remainder-shell or corner of coal, the best modern practice aims at doing so.

The object of this paper, therefore, is to ascertain whether the ordinary and unavoidable loss, which the Royal Commission in 1871 believed to be 10 per cent. under favourable conditions, can be or has been reduced, and if so, to what extent. It

is not quite clear from the report whether the 10 per cent. is an average figure applicable to coal-working generally, taking the different modes in favourable circumstances into account, or whether it applies more immediately to one or other system found by experience in some limited district to have been particularly successful. One would gather from the evidence upon which the report is based that most of the trials made to ascertain the loss had not been of a very extended kind, either in respect of time or area: and it is obvious that some of the data in the evidence are incorrect: for example, more than one witness assumes the weight of coal to be only 121 tons per inch thick per acre. It is perhaps more than we need do, but let it be assumed that the 10 per cent. was arrived at from results obtained under different modes of working and embracing a large output.

When we bear in mind that the annual output of coal in Great Britain is now about 220,000,000 tons, we shall realize that the prevention of the whole or a great part of even 10 per cent. of loss is no mean saving of the nation's resources. If it can be proved that there has been a material reduction in the percentage of what was considered unavoidable waste in 1871, then it may certainly be predicated that the avoidable waste has been diminished in a more marked degree.

Many of the largest collieries in Lanarkshire have been opened since 1871, and as the conditions of working are favourable and the best modern methods have been practised in these collieries, it is to be expected that the results obtained have been quite equal to the most successful results in coal-mining during the last 30 years, taking the country as a whole.

With the view, therefore, of ascertaining the ordinary or unavoidable loss in the working of coal under favourable circumstances and according to the most approved methods, a number of collieries opened up in Lanarkshire since the date of the Royal Commission of 1871 (the earliest about 1872, and the latest a few years after) have been selected, and a careful comparison has been made between the quantity proved by survey and measurement to have been worked in these coal-fields and the actual quantities raised from them.

For the information of members who are not acquainted with the district, it may be stated that in the valley of the Clyde from Cambuslang on the north-west through Bothwell and Hamilton to

Larkhall on the south-east the five most important seams of coal, naming them in descending order, are the Ell, Pyotshaw, Main, Splint and Virgin seams. These seams vary considerably both in quality and thickness, and in the vicinity of Cambuslang, the Pyotshaw and Main seams lie contiguous and are worked as one seam, while the Virgin lies usually a few feet under the Splint seam. In the neighbourhood of Hamilton, what is called the Splint seam is really the Splint and Virgin in one.

The depths of these seams from the surface at several points are as follows:—

| | Ell Seam. Feet. | Pyotshaw Seam. Feet. | Main Seam. Feet. | Splint Seam. Feet. |
|---|---|---|---|---|
| Near Cambuslang ... | 408 | 459 | 462 | 558 |
| Hallside ... ... ... | 1,290 | 1,332 | 1,356 | 1,446 |
| Bothwell ... ... ... | 900 | 981 | 984 | 1,050 |
| Hamilton ... ... ... | 642 | 702 | 714 | 780 |
| Near Larkhall ... ... | 450 | 504 | 528 | 600 |

The seams vary in thickness at different places in the district referred to as follows:—Ell seam, 36 to 84 inches; Pyotshaw seam, 30 to 48 inches; Main seam, 36 to 54 inches; Splint seam, 33 to 45 inches; Virgin seam, about 30 inches; and when the Splint and Virgin seams are together, 58 to 84 inches.

The roofs are on the whole good, and the conditions for working favourable.

The systems of working are stoop-and-room and longwall, either system being followed where the thickness of the seam and local conditions favour its adoption. The workings vary in extent in the different collieries. Roughly the area exhausted in each seam in the collieries here dealt with may be taken as follows:—Ell, 2,313 acres; Pyotshaw, 705 acres; Main, 1,506 acres; Splint, 1,018 acres.

It is unnecessary to state which particular collieries have been selected in the enquiry, suffice it to say that they are within the district just described.

Table I. shews the results obtained at five collieries; the second column shews the quantity worked as ascertained by measurement; the third column, the total quantity produced and sold, and used for fuel at the colliery; the remaining columns, a comparison of these quantities, indicating the percentage that each is over or under the other.

The measurement-quantities are made up from the result of half-yearly surveys and measurements of the coal worked during the whole lifetime of the collieries till now. The utmost accuracy is in this way attained, because the outside limits of the coal have been seen and correctly recorded, and the thicknesses of the seams, whatever their variation, got each half year, while the specific gravity of the coal in each seam at each colliery has been got by actual trial, the weight per inch per acre varying from about 126 to 128 tons. It must be understood that these measurement-figures are not subject to any deduction in respect of faults or from any other cause. They represent the quantity of marketable coal, which has been worked, and which, under a perfect system of working, ought to have come out of the pit.

TABLE I.—COMPARISON OF MEASUREMENTS AND DISPOSALS OF PRODUCE OF FIVE COLLIERIES.

| No. of Colliery. | Quantities worked as ascertained by Measurements. | Total Disposals. | Excess of Disposals over Measurements. | | Excess of Measurements over Disposals. | |
|---|---|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Per Cent. | Tons. | Per Cent. |
| 1 | 4,880,174 | 4,783,227 | — | — | 96,947 | 1·98 |
| 2 | 2,116,319 | 2,181,806 | 65,487 | 3·09 | — | — |
| 3 | 4,408,847 | 4,500,760 | 91,913 | 2·08 | — | — |
| 4 | 2,004,781 | 1,962,241 | — | — | 42,540 | 2·12 |
| 5 | 2,009,243 | 2,045,302 | 36,059 | 1·79 | — | — |
| Totals | 15,419,364 | 15,473,336 | 193,459 | 0·35 | 139,487 | — |

The figures under the heading of disposals represent the whole coal, large and small, as weighed on the railway-wagon and cart weighing-machines at the colliery and sold or otherwise disposed of, including workmen's fire-coal, and the fuel which has been used at the pits for raising steam and for other purposes. The last item, that of colliery-fuel, is not usually weighed with exactness, as the arrangements at the pit-head seldom allow of this being done, but it is customary to make a daily or weekly estimate of the quantity used at each colliery based on periodical trials. It may be taken that the quantities of colliery-fuel included with the disposals in the table are reasonably correct.

Table I. shews that while in some cases there is a deficiency in the disposals as compared with the measurement indicating a loss in working there is in others an excess which seems to point to a larger output having been got than the measurement shews to be

possible. But this may not really be so, because it has to be borne in mind that a considerable proportion of stones and dirt may be put out by the miner and loaded into the cart or railway-wagon and so be weighed as coal, especially at collieries where the system of cleaning is defective or the operation not efficiently supervised. It is to be expected that where the newest cleaning or washing-plant is in use the excess should not be on the side of disposals. Now it so happens that the colliery, shewing the largest excess of disposals over measurement, is one which had no washing-plant all the time, and that which shews the next largest had no washing-plant for more than half of the period under consideration.

The result of the comparison of the produce of these five collieries shews that two collieries are deficient in their production to the extent of about 2 per cent., and three show production over measurement to the extent of from $1\frac{3}{4}$ to 3 per cent., the difference on the whole, when thrown together, being under $\frac{1}{2}$ per cent. of production over measurement.

TABLE II.—COMPARISON OF MEASUREMENTS AND DISPOSALS OF PRODUCE OF SIX COLLIERIES.

| No. of Colliery. | Quantities worked as ascertained by Measurements. | Total Disposals. | Excess of Disposals over Measurements. | | Excess of Measurements over Disposals. | |
|---|---|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Per Cent. | Tons. | Per Cent. |
| 6 | 2,304,716 | 2,105,194 | — | — | 199,522 | 8·65 |
| 7 | 4,219,490 | 4,356,031 | 136,541 | 3·23 | — | — |
| 8 | 3,774,725 | 3,631,255 | — | — | 143,470 | 3·80 |
| 9 | 2,899,446 | 2,961,772 | 62,326 | 2·15 | — | — |
| 10 | 3,398,257 | 3,077,190 | — | — | 321,067 | 9·44 |
| 11 | 6,425,934 | 5,903,178 | — | — | 522,756 | 8·13 |
| Totals | 23,022,568 | 22,034,620 | 198,867 | — | 1,186,815 | 4·29 |

Table II. contains similar figures in connection with six other collieries, where the data for a measurement of the coal excavated are not so full as in the case of the collieries in Table I. in respect that, while the figures in Table I. are taken from surveys where a comparison was made annually between measurement and disposals, those of Table II. are compiled from one measurement of the whole excavation in each seam as shewn at the present date on the colliery-plans, and the thicknesses of the seams have not in all cases been shewn on the plans sufficiently numerous to ensure a perfect average over each area measured.

The results, as was to be expected, shew greater differences than in Table I., four collieries having a deficiency of production as compared with measurement of from $3\frac{3}{4}$ to $9\frac{1}{2}$ per cent. and two an excess of from $2\frac{1}{4}$ to $3\frac{1}{4}$ per cent., the average of the whole together being a deficiency of $4\frac{1}{4}$ per cent.

If we bring the totals of the two tables together as shewn in Table III., we find that there has been produced and disposed of at these eleven collieries coal to the extent of 37,507,956 tons, with an average loss of only $2\frac{1}{2}$ per cent.

TABLE III.—CONTAINING A SUMMARY OF TABLES I. AND II.

| Table. | Quantities worked as ascertained by Measurements. | Total Disposals. | Excess of Measurements over Disposals. | |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Per Cent. |
| I. | 15,419,364 | 15,473,336 | — | — |
| II. | 23,022,568 | 22,034,620 | — | 4·29 |
| Totals | 38,441,932 | 37,507,956 | 933,976 | 2·43 |

No doubt the question will be asked, how do the two systems of working compare in the matter of loss? It has not been convenient to separate out the disposals appertaining to the two modes of working at some of these collieries, but Table IV. shews a comparison so far as this can be done, embracing areas of 2,316 acres of stoop-and-room, and 2,177 acres of longwall. While the deficiency on the whole, combining the output from the two systems is 2·3 per cent., that by stoop and-room shews 3·7 per cent., while that by longwall is only 0·11 per cent. These figures there fore go to show that the longwall system is the more thorough of the two by $3\frac{1}{2}$ per cent.

TABLE IV.—COMPARISON OF THE LOSSES IN WORKING BY LONGWALL AND STOOP-AND-ROOM.

| System of Working. | Quantities worked as ascertained by Measurements. | Total Disposals. | Excess of Measurements over Disposals. | |
|---|---|---|---|---|
| | Tons. | Tons. | Tons. | Per Cent. |
| Worked by longwall | 12,008,239 | 11,994,829 | 13,410 | 0·11 |
| Worked by stoop-and-room | 18,379,006 | 17,687,594 | 691,412 | 3·70 |
| Totals | 30,387,245 | 29,682,423 | 704,822 | 2·30 |

It may be well to state that the measurement-figures in the tables include, in the case of stoop-and-room workings, not only

the coal where the pillars have been entirely taken out and the seam exhausted, but also where the first working only has been carried forward, leaving the pillars still unworked. Seeing that the greater loss is in the pillar-working, it follows that the disposals figures applicable to these areas of first working are more favourable than if the whole seam had been exhausted, and to this small extent the results shew too well; but the areas of forward working, being small as compared with the totally exhausted areas, the average percentages in Tables III. and IV. would be increased by only about ¼ per cent.

It cannot, of course, be claimed that only the 2½ per cent. or so brought out in Tables III. and IV. is the whole marketable coal left in the workings and represents the full proportion of unavoidable waste or loss; because, as has been already indicated, stones and dirt find their way to the market among the coal, and coal corresponding thereto in weight must be held as remaining in the workings. What the proportion of these foreign substances may be it is very difficult to estimate, as the conditions of working, as well as the degree of efficiency of the cleaning processes, vary so much. But it would probably not be wide of the mark if 2½ per cent. all over were allowed for this. It is questionable, however, whether the Royal Commissioners took this into account; the probability is that they did not. If so, then 2½ per cent. is the figure to be compared with the 10 per cent. of their report.

It appears, therefore, that we may conclude, from the figures shewn, that the progress of mining science during the last 30 years has resulted in a reduction of the unavoidable waste or loss in working from 10 to about 5 per cent., or, more probably, 2½ per cent. It is a somewhat startling fact that even 5 per cent. of saving on the present annual output of Great Britain is equal to about a fourth of the entire output of these eleven large Lanarkshire collieries from their commencement till the present day. But there is no doubt that the improvement exceeds 5 or even 7½ per cent. so far as Lanarkshire is concerned, because prior to 1871 the loss in working exceeded 10 per cent., chiefly due to the defective methods of extracting the pillars in the modern system of stoop-and-room working, a system which had not then been thoroughly established.

Coming now to the answer to the query which forms the title of this paper, it cannot be said that the least possible waste in working coal has yet been determined, but enough has been stated

to shew that progress is being made towards a definite and satisfactory result. If in the past generation the mining engineers and managers of Lanarkshire have succeeded in effecting so substantial a saving in the working of coal as that above indicated, there is no reason why they and their successors should not go farther in the same direction until the irreducible minimum is reached, and the sooner it is reached the better for our country.

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The PRESIDENT (Mr. J. S. Dixon) remarked that the subject of the least possible waste in working coal was most interesting, and at the present time, when a Royal Commission on coal-supplies had been appointed, a paper touching upon it was of great value. Mr. Barrowman had brought out figures of which the members had all just reason to feel gratified. If they compared 10 per cent. with 0·11 per cent. they really had a comparison between the two periods so far as set forth in the report of the Royal Commission of 1871, as he took it that the 10 per cent. of loss assumed by the last Commission referred to the best practice. It seemed to him that, as the thicker seams became exhausted, the longwall system would be universally adopted for the extraction of coal. He believed that the irreducible minimum of loss in working would only be reached through that method.

Mr. JAMES HAMILTON (Glasgow) said Mr. Barrowman had shewn that progress had been made during the period covered by his paper in the reduction of avoidable waste in working; but his figures did not show how much progress had really been made compared with say 10 years earlier than 1870. He believed it was after 1860 that it became customary to stipulate in leases in Scotland that the pillars in stoop-and-room workings were to be systematically removed. Much had to be learned by subsequent experience as to the best size of pillar to be formed in the first working for extraction with the minimum loss, and also as to the best method of working pillars after they were formed. At first, there was a tendency to leave the pillars much too small, with the result that coal was lost by crushing of pillars when stooping began. The necessity of increasing the size of pillars as greater depths were reached was not adequately realized, and sound practice in this respect was delayed. The limited area of the Lanarkshire thick coal-seams worked by stoop-and-room had pre-

vented the full benefit of experience being obtained as, to a larg extent, the working had been simultaneous, and it is only nov when the necessity for it is wellnigh over that the results of experi ence can be and are being applied. He had little doubt that i a comparison could be made of the loss, during the earlier year of the period dealt with by Mr. Barrowman, with the bes practice now, it would show very considerable progress. I appeared to him that mining-engineers often forget the proverl "Mony littles mak' a muckle," for he had frequently been tol by colliery-managers that "not a pound of coal" was being los in stooping when it was apparent to observation and by measure ment that this was far from being the case. One source of loss the importance of which seemed to him not to be realized, was i the unnecessarily thick "skins" frequently left alongside th stooping-place to keep back the fallen roof in the waste. Anothe loss arose through not keeping a vertical face of coal on the stoop side of a stooping-place, and leaving the coal projecting at th roof and pavement beyond the coal in the centre of the seam This is very common in working thick coal-seams—such as th Ell and Splint seams—about Hamilton. The result of this i that a strip of coal of triangular section is lost both at the roof an pavement along each stooping-lift, by the fall of the roof cover ing it. This loss was certainly an avoidable one by care on th part of miners and officials, and though it seems small, it amount to a surprising percentage when calculated out. Apparently th irreducible minimum of loss is nearly reached in longwall work ing, as a loss of 0·11 per cent. could scarcely be improved upon and the same goal is being approached by stoop-and-room work ing, as the system itself will soon vanish with the thick seams.

Mr. GEORGE A. MITCHELL (Glasgow) asked the periods fo which the measurements were taken, and whether any of the coa to which the tables referred was worked as far back as 1872.

Mr. J. BARROWMAN said that the first of the collieries wa opened about 1872, and some of them probably as late as 1880.

Mr. G. A. MITCHELL said that his reason for asking the questio was to ascertain whether the average given in the statement was fair average for the loss over the whole period included in th working. If the measurements included the period as far back a

1872 or 1873, then the results for the later part of the period would probably be better than the average of the whole period as shewn in the table. Mr. Barrowman had furnished the members with information which was available to very few, and figures which would be useful for reference for many years to come. The results were specially valuable in view of the fact that a Royal Commission on the coal-question was sitting at the present time, and might be quoted with advantage to the credit of Lanarkshire. There was one point which occurred to him, and it was this, that in some of the seams there were ribs of dirty coal which he supposed would not be included in the measurements. Take, for example, the Ell coal-seam in the Cambuslang district in which there is a rib of mixed coal and stone called the "camper." This dirty coal was often sent up by the miners and would sometimes escape the pickers on the picking-tables and pass into the wagons. This might affect the measurements to a certain extent. These ribs were not altogether dirt and yet were not coal, and could not be fairly included in measurements. Generally, he might say that, knowing the care with which all measurements were taken by the engineers connected with the Hamilton Estates, he thought they might accept the results as exceedingly accurate.

Mr. A. Blyth asked whether the thicknesses of the seams were taken from the surveyors' measurements or those of the managers.

Mr. J. Barrowman replied that the measurements were those of the surveyors.

Mr. R. T. Moore thought that on the whole the members might have been prepared to expect that the coal would be wrought at the small percentage of loss stated by the writer. It was to be remembered that, in addition to the loss in working mentioned, there was a loss of coal in barriers, in stoops for preserving buildings, shafts, and other surface-erections, all of which would materially bring the percentage up to a higher figure than that shown. The actual results given by Mr. Barrowman, however, were very satisfactory. It was somewhat difficult to say when coal was really lost to the country. He had been recently at a colliery where pillars in the Ell coal-seam, abandoned 40 years ago, were being worked out. No doubt a few years ago, these would have been reckoned as lost coal.

The PRESIDENT (Mr. J. S. Dixon) thought that the proprietors of these coal-fields where they were now working the head-coal owed a vote of thanks to the miners of some 30 or 40 years ago who left parts of the stoops in the original workings. Had they not done so this head-coal would have been entirely lost. Sufficient coal had been left in to allow the head-coal to settle down. This was bad mining practice at the time, but the result was to enable the head-coal and stoops left to be now recovered.

Mr. R. W. DRON (Glasgow) asked whether the disposals were calculated on the railway-weights or the outputs.

Mr. J. BARROWMAN replied that the outputs had no place in the calculations; the disposals were the railway-weights.

Mr. R. W. DRON said that while they were only losing 2·3 per cent. from the coal in a particular area, the question came to be what were they losing in the whole coal-field? If they had a section containing, say, 40 feet of coal in the different seams, how much would be got out? Would they expect to recover 97·7 per cent. of that coal? He was satisfied that in an area of some 40 or 50 square miles, after making provision for faults, barriers, the security of houses, etc., not more than 66 per cent. of the coal would be extracted. The subject, however, was one which would require to be very carefully studied before Mr. Barrowman's paper could be discussed at all seriously. What, he asked, was the definition of the phrase "loss in working?" What did the Royal Commission understand by loss of working, when they stated that it was 10 per cent., and what did Mr. Barrowman understand it to be in the cases where he demonstrated it to be 2·3 per cent.? In both cases was the loss being estimated on the same basis? Did the Royal Commission mean the real loss in working as Mr. Barrowman understood it, or was it loss in working in a more general sense? He could give an instance of a colliery in Lanarkshire, in which the seams from the Ell to the Splint had been extracted, within a mile or so of the collieries to which Mr. Barrowman referred, where the actual exhaustion was only equal to two-thirds of the area of the leasehold. If, however, the net excavation shewn accurately by the surveyors' measurements was dealt with, instead of the whole area, the results would probably be somewhat similar to those given by Mr. Barrowman. Then in deal-

ing with thinner coal-seams, where a machine is used for holing, the small coal of the holing was frequently useless, and that would involve a distinct loss in working. Another instance where a great quantity of coal had been lost in the past was in the Ell seam in the Larkhall district, where the roof consisted of soft white pipe-clay, and several feet of coal had been left to support the roof. No system of mining could entirely get rid of the loss caused by a soft roof, such as that mentioned. These were some of the points of dubiety that one felt inclined to raise in connection with a subject like this; but the paper would require to be more carefully read and the figures examined.

Mr. J. Barrowman observed that the scope of his paper was very much restricted. "What was the least possible waste in working coal?" Given a certain area, which by measurement was demonstrated to be capable of producing a certain number of tons, what was the actual number of tons which that area did produce? The paper had nothing to do with barriers left for the protection of marches, buildings or shafts, or with the question of protecting or damaging one seam by another. All these matters were taken up by the Royal Commission in the eleven causes of loss mentioned. What he conceived the Commission to include in the 10 per cent. was the ordinary and unavoidable loss in the strict working of the coal. He thought that a study of the report, of which he had given an extract, would make that point clear.

The President (Mr. J. S. Dixon) thought that Mr. Barrowman was correct in his opinion. The present Commission would take evidence on these points, and also as to the loss of barriers, pillars, troubles, and so forth. The question of the loss in the strict working of the coal was a separate conclusion altogether. He thought, on the whole, that the results contained in Mr. Barrowman's paper were very good indeed. Another of the questions which would come before the Royal Commission was that of determining the best way of ascertaining the amount of coal that was left in pillars for the support of buildings, barriers, etc. He knew one place where there was a loss of 10 per cent. on a barrier, but that was a very unusual case. The barriers in the Lanarkshire coal-fields were usually 15 feet thick round the marches. The whole question, however, was one on which evidence would be received by the Royal Commission.

Mr. J. BARROWMAN said that there must be a great deal of uncertainty surrounding that question. A proprietor might, as a matter of prudence, leave large portions of coal in pillars for the support of surface property, while his successors might work out the coal. It was very difficult to come to any sound conclusion on the point.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE, FEBRUARY 8TH, 1902.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on January 25th and that day.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. EMERSON MUSCHAMP BAINBRIDGE, Mining Engineer, Shirland House, Alfreton, Derbyshire.

Mr. WILLIAM BARROW, Colliery Engineer, Seaton Burn Colliery, Dudley, R.S.O., Northumberland.

Mr. ARTHUR LEO CHAMBERS. Mining Engineer, Whitehall Club, London, S.W.

Mr. WILLIAM HASLAM CROSS, Mining Engineer, 77, King Street, Manchester.

Mr. ROBERT DIVES, Mechanical and Consulting Engineer, Industries Office, Acutt's Arcade, Durban. Natal, South Africa.

Mr. ROBERT BERTRAM HEDLEY, Mechanical Engineer, c o Mr. W. Zimpel, Hay Street, Perth, Western Australia.

Mr. JOHN HUMBLE, Mining Engineer, West Pelton House, Beamish, R.S.O., County Durham.

MR. ROBERT LINDAY, Mining Engineer, Netherton Coal Company, Limited, Netherton Collieries, Newcastle-upon-Tyne.

Mr. TIMOTHY ROBINSON, Mechanical Engineer, Ryhope Colliery, *via* Sunderland.

Mr. ARTHUR GEORGE BOOTLE WILBRAHAM, Assistant Mining Engineer, Mina de San Domingos, Mertola, Portugal.

ASSOCIATE MEMBERS—

MR. R. G. STANLEY ANTHONY, P.O. Box 186, Rossland, British Columbia.
Mr. ARTHUR O'CONNOR, K.C., Judge of County Courts of Durham, The College, Durham.

ASSOCIATES—

Mr. HEWAN ARCHDALE, Mining Student, Church Street, Quebec, near Durham.
Mr. FRANK FORSTER, Back-overman, 22, Gowland Terrace, Wheatley Hill Colliery, Thornley, R.S.O., County Durham.
Mr. GEORGE CATRON NELSON, Under-manager, Garesfield Colliery, near Lintz Green, R.S.O., County Durham.
Mr. THOMAS WAKEFIELD PARKIN, Back-overman, 17, Gowland Terrace, Wheatley Hill Colliery, Thornley, R.S.O., County Durham.
Mr. THOMAS ROBSON, Overman, Team Colliery, Low Fell, Gateshead-upon-Tyne.
Mr. SAMUEL WANE, Shot-lighter, 11, Victor Street, Hollinwood, Oldham, Lancashire.

STUDENTS—

Mr. GEORGE OCTAVIOUS HARPER, Mining Student, Cardiff Square, High Spen, Lintz Green, R.S.O., County Durham.
Mr. ERNEST HUNTER OLIVER, Mining Student, Cornsay Colliery, County Durham.
Mr. FRANK THORNTON, Mining Student, Cornsay Colliery, County Durham.

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## THE LATE MR. E. VUILLEMIN.

Mr. JOHN DAGLISH (Past-president) referred to the death of Mr. E. Vuillemin, one of the leading mining engineers in France, and who was elected an honorary member in 1878 owing to the important position which he held in connection with large collieries in that country. He moved that a vote of condolence be sent to the members of his family.

The vote of condolence was unanimously adopted.

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## CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, GLASGOW, 1901.

The report of the proceedings of the Corresponding Societies Committee of the British Association for the Advancement of Science, and also that of Mr. J. H. Merivale, the delegate representing the Institute, was read as follows:

BROOMHILL,
*September 22nd*, 1901.

TO THE PRESIDENT AND COUNCIL OF THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENTLEMEN,

Two Conferences of the Delegates of the Corresponding Societies were held on September 12th and 17th.

The question of the postage of scientific *Transactions*, I was informed by Dr. Garson, had been considered by the Committee, and they had decided that it was a subject not for the Conference of Delegates, but for the Economic Section. I therefore both wrote and saw Dr. Cannan, the recorder of that Section, who promised to forward the matter.

At the meetings of the Sections, the following papers were read on subjects of interest to mining engineers :—

Presidential Address ("Locomotion on Land") to the Mechanical Section. By Col. R. E. Crompton.

"Resistance of Road-vehicles to Traction." By Prof. Hele-Shaw.

"The Present and Future of Railway Rolling-stock." By Mr. Norman D. Macdonald.

"A Recording Manometer." By Mr. J. E. Petavel.

"Output of Coal from the Scottish Coal-fields." By Mr. R. W. Dron.

"Geographical Conditions affecting British Trade." By Mr. G. G. Chisholm.

"Report of the Committee on the Increase of Underground Temperature Downwards in Various Localities of Dry Land and Under Water." By Prof. J. D. Everett.

"Report of the Committee on Seismological Investigations." By Prof. J. Milne.

"The Transport of British Timber." By Mr. Samuel Margerison.

"The Scottish Ores of Copper in their Geological Relations." By Mr. J. G. Goodchild.

"The Source of the Alluvial Gold of the Kildonan Gold-field, Sutherland," By Mr. J. M. Maclaren.

"The Occurrence of Covellite in Association with Malachite in the Sandstone of Kingsteps, Nairn." By Dr. W. Mackie.

"The Commercial Importance of Aluminium." By Prof. E. Wilson.

"Artesian Water-supply in Queensland." By Dr. R. Logan Jack.

I am, Gentlemen,
Yours truly,
JOHN H. MERIVALE.

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The PRESIDENT (Mr. J. G. Weeks) moved that a vote of thanks be accorded to Mr. J. H. Merivale, for his services as delegate and for his report.

The resolution was cordially approved.

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Mr. W. B. WILSON, jun., read the following paper on "Tapping Drowned Workings at Wheatley Hill Colliery."

# TAPPING DROWNED WORKINGS AT WHEATLEY HILL COLLIERY.

By W. B. WILSON, Jun.

Thornley colliery began to draw coals in 1834. The Harvey seam would then probably not be extensively worked, but in 1858 the workings had reached a considerable extent in all directions. The coals were brought to the shaft by a hauling-engine and boiler, both placed underground: the boiler-flue being made in the coal-seam.

In June 1858, the coal adjoining the flue-way took fire, and it was found necessary to drown it out; and a considerable quantity of water ran into the face of the east headways district, at that time being driven in the whole mine (Fig. 1, Plate III.). There would probably be no opportunity of surveying the face of this district, although the plan might be drawn, roughly, by making use of such information as was then available. The south way, out of the east headways, continued working until 1861, when the Harvey seam was laid in. There would probably be an opportunity of surveying the south way and other districts, which were abandoned either at this date, or previously, except the east headways, and of having the plans of the workings completed to the extreme extent of the workings, although there can be no certainty of this having been done. After the seam was laid in, the water in the east headways gradually rose, until it closed all connections with the south way, leaving the higher workings of the south way water-sealed but dry.

The Harvey seam has always made a considerable quantity of gas, and this, at intervals, burst out of the south way, through the water, and towards the shaft. This gas is supposed to have been the cause of an explosion, which occurred in the downcast shaft, on August 23rd, 1865.

On May 8th, 1875, a disastrous fire practically destroyed all the surface-plant, and timber in the shaft. The feeders of water which had previously been pumped to bank, were necessarily allowed for a time to run into the workings of the Harvey seam, which had up to this date, with the exception of the east side, been kept clear of water. No further attempt was made to keep down this water, and the downcast shaft, below the Hutton seam, was blocked with débris from the fire. On March 24th, 1881, the water had risen to a level of 53½ feet below the Hutton seam. On April 23rd, 1883, to 47 feet below; and on December 8th, 1884, to 43½ feet below that seam (Fig. 2, Plate III.).

After the fire, the downcast shaft was filled with stones and other rubbish, to about 25 feet below the level of the Hutton seam. It is supposed that this was done, because there was a risk of the gas from the Harvey seam escaping into the shaft through the water and débris.

Between 1884 and 1887, all operations at Thornley colliery were suspended. Meanwhile, the water rose above the level of the Main coal-seam, to an altitude of about 120 feet below sea-level.

On May 11th, 1888, a commencement was made to draw the water with water-cages. On February 9th, 1889, the water was lowered to the level of the Hutton seam hanging-on, and was afterwards lowered to about 20 feet below this level (Fig. 2, Plate III.). The water has since been maintained about this point, although it was never lowered to the same level in the upcast staple between the Harvey and Hutton seams, but stood about 14 feet below the level of the Hutton seam, until disturbed by the operation about to be described in this paper.

The Harvey seam at Wheatley Hill colliery was first worked in 1892; and in 1894, some of the working-places in the north-west district began to shew signs of water. This, taking into consideration the proximity of the drowned workings of the Harvey seam of Thornley colliery, was rather alarming, although the Wheatley Hill workings were still, according to the plans, about 525 feet from the nearest workings of Thornley colliery in the Harvey seam. The working-places where the water had made its appearance were stopped, and it was decided to leave a barrier of at least 450 feet of solid coal against the workings of the Harvey

seam of Thornley colliery, as delineated on the plan, as it was possible that this plan was incomplete.

Early in 1900, it was decided to hole into the Thornley workings from Wheatley Hill colliery, so as to run off the water to the Wheatley Hill pit, through the Burnside safety-boring apparatus.

A vertical hole was drilled from the Busty seam of Wheatley Hill colliery, at a point, where a little water was made at a crack in the roof, lying in the same course as the edge of the goaf in the overlying Harvey seam of Thornley colliery, and in the face of a place, A, which had previously been driven a few feet under the goaf for this purpose (Figs. 1 and 2, Plate III.). This hole penetrated the goaf on February 3rd, 1900, but as the goaf was close, only a very little water came away, with a little gas. The hole was then plugged and left.

A narrow headway, BCD (8 feet wide), was then driven, with bore-holes, from the north-west district of the Harvey seam of Wheatley Hill colliery in the direction of the east headways of Thornley colliery: this was the lowest point of the Thornley workings (Figs. 1, 2 and 3, Plate III.).

The bore-holes were drilled with a hand-rotated stone-drilling machine of suitable height, constructed so that the feed-worm and nut might be quickly released, and the rods withdrawn through the stand of the machine. The feed-worm had a Whitworth thread, 6 turns to the inch, $1\frac{3}{8}$ inches in diameter, the screw being 2 feet $7\frac{1}{2}$ inches long. The boring-machine had a double handle, with a 12-inch throw, and was worked by two men turning together. Ratchets were only used when going through a piece of pyrites, and this did not often occur (Figs. 4 and 5, Plate IV.).

The Burnside safety-boring apparatus consists of the tube which is wedged into the hole; the wedges; and the necessary taps and glands outside the hole. Special drills are used to enlarge the outer end of the bore-hole to the necessary diameter so as to admit the tube and wedges; and bore-rods, of round section, may be added, as the hole advances, without opening the apparatus.

The hole is drilled of the diameter, it is intended to continue, for a length of about 5 feet. A length of $3\frac{1}{4}$ feet is then enlarged

with the intermediate drill (Figs. 7 and 8, Plate IV.), and 2 feet 10 inches of this hole is again enlarged with the large drill (Fig. 9, Plate IV.), leaving a shoulder, C, against which the water-tight joint is made (Figs. 4 and 5, Plate IV.).

A thick india-rubber washer is placed on the end of the tube against the flange, C, and the four wedges and the machine are pushed carefully into the hole, the upper and lower wedges, E, E, being placed with their heads against the flange, D; and the side-wedges, G, G, are fixed against the flange, C. When the india-rubber washer reaches the shoulder, C, left by the large drill, the upper and lower wedges are driven in with a hammer, and the side-wedges are drawn outward by turning the nuts, U, on the bolts, V, fitted for this purpose. While the side-wedges, G, G, are being drawn out, the tube moves into the hole for a certain distance, and compresses the india-rubber washer. This compression can be assisted also by setting the drilling-machine, and pressing the apparatus into the hole with the feed-worm (Figs. 4 and 5, Plate IV.).

The apparatus, when set, can be tested by means of the hydraulic test-pump (Fig. 14), and pressure-gauge, H (Fig. 4); and if well set there will be practically no leakage of water or gas at a pressure of 200 pounds per square inch. The test-pump may be fitted either upon the gland, M, or the tap, N; but the pump, as supplied with the apparatus, will only work efficiently in a vertical position, owing to the valves with which it is fitted (Figs. 4 and 5, Plate IV.).

The tap, N, may be left open while drilling a horizontal hole in order that the drillings may escape, if there be sufficient water to bring them out, and the tap, P, may be used for the same purpose in the case of a vertical hole (Fig. 4, Plate IV.).

If any other section of rods than the round section, supplied with the machine, be used, these rods should be added next to the piston-rod, R (Figs. 4 and 5, Plate IV.), so as to keep this piece working through the gland, M, and next to the feed-worm. In this case, it will be necessary to open the gland, M, every time another rod is added.

If the round section of rods be used, they may be added outside the apparatus, between the feed-worm and the piston-rod, R; and it is then only necessary to open the gland, M, when changing a drill; or, if the drill be not clearing itself, to remove the débris.

At T T, are pieces of india-rubber, which can be screwed against the rods, and these will, if necessary, make the apparatus almost water-tight, even when the gland, M, is open. This arrangement is adopted so as to guard against the possibility of water breaking away while the rods are being withdrawn, for any reason, from the hole. The large tap, L, can only be closed when the rods are drawn out of the apparatus. The gland, M, makes a gas- and water-tight joint with the round rods, or the piston-rod, R. The barrel and taps of the apparatus are made of gun-metal, and the wedges, etc., of iron.

The chief advantages of the Burnside safety-boring apparatus are:—(1) The comparative ease and quickness with which it can be securely set, or withdrawn. (2) It can be tested with the hydraulic pump, before proceeding to bore. (3) The remarkably small leakage of water and gas, when the apparatus is well set. (4) If any taps are for any reason left open, when the rods hole, they can be easily closed. (5) The ease with which pipes, to conduct the water away, can be connected to the machine, when necessary.

The writer found, in holes 54 feet long, that two men drilled an average length of 48 feet in a shift.

In the first length of 348 feet of the headways, 8 feet wide, B C, the flank-holes were drilled at intervals of 9 feet, at an angle of 30 degrees from the line of the place, alternately 27 feet and 54 feet long; and the straight-on hole was kept 54 feet in advance of the coal-face (Fig. 3, Plate III.). For the remaining length of 132 feet, C D, previous to the holing, the flank-holes were made 54 feet long. In the south-east headways district of Thornley colliery, the bords were driven 12 to 15 feet wide, and the walls 7 or 8 feet wide.

Considerable difficulty was, at first, experienced in boring holes as long as was desired, without their penetrating into the roof of the seam. The holes were, at first, set away about the middle of the seam, for convenience in turning the handle, and having the same rising inclination as the seam; but it was soon found desirable to incline the holes slightly towards the bottom of the seam; and even these holes penetrated into the roof-stone more frequntly than into the bottom-stone, if continued far enough, but few holes got either into top or bottom stone within 40 feet. The seam is about 3 feet 8 inches thick.

Very few of the straight-on holes were lost through deviating to either side of the place. Some of the straight-on holes were continued as the face advanced, to a total length of more than 100 feet; 95 feet being the greatest length on any hole at any one time.

The tendency of the holes to rise into the roof may have been due to the cutting-edge of the drill being larger in diameter than the rods (Fig. 5, Plate IV.). The rods would of their own weight lie along the bottom of the hole, while the centre of the drill would be in the centre of the far end of the hole; this position would give to the drill and the last few rods a slight upward inclination, and would continually tend to cause the hole to rise towards the roof.

When the drill encountered pyrites or any other irregularity in the seam, the holes were diverted from their course in any direction, sometimes so great that the rods would hardly follow the new line of the hole.

In the beginning, the Burnside safety-boring apparatus was wedged into every hole, and this took a considerable time; moreover, if a hole was not bored to its distance at the end of the borer's shift, the apparatus had to be removed out of the way of the coal-hewers and afterwards reset on the same hole. It was therefore decided only to use the Burnside apparatus in holes, shewing signs of water; consequently it was only set two or three times before September 13th, 1900, when a straight-on hole, which had so far not been unusually damp, reached a breaker in the coal, E, and encountered a feeder of about 10 gallons of water per minute (Fig. 3, Plate III.). This hole happened to be 67 feet long, as the flank-holes were not due to be bored, and the borers had therefore continued the straight-on hole past its usual distance.

After setting the apparatus on this hole and closing it, the pressure in a few minutes rose to 85 pounds per square inch, which agreed, at the time, with the level of the water in the Harvey staple at Thornley colliery. There was a dropping of water at one or two of the glands and a very slight leakage out of the hole, and the total leakage may be estimated at less than 1 quart of water in the hour; and this speaks strongly for the utility of the apparatus, which had been in the pit for some months, and had been used several times previously. The apparatus was left in the hole

until a cistern was set, and pipes laid from the cistern, to conduct the water to the standage.

On September 20th, 1900, the taps were turned on, but the quantity of water did not increase as was expected, and on the following day the hole was bored another foot, through the Burnside machine. This produced more water than the cistern and pipes would carry away—probably about 60 gallons per minute—and the taps were set so as to allow of the issue of about 40 gallons per minute—the full carrying capacity of the pipes (Fig. 15, Plate V.).

This quantity not being so large as was desired, on September 26th the cistern being removed, the apparatus was coupled direct to the pipes, and the tap on the machine opened to its full extent. The water then increased to about 50 gallons per minute. As this feeder was still not considered sufficient, the rods were again put through the machine, on October 11th, and the hole bored a further 3 feet. This gave a further increase of water, to about 80 gallons per minute.

This feeder then slowly became less, probably due to loss of pressure, and on November 10th, although it was thought that the hole was bored through, the rods were again put in, and 2 feet farther bored to F, still in broken coal (Fig. 3, Plate III.). The water then came away with great force, clearly shewing that the hole was through, and that it had not previously been so. The quantity of water running through the pipes then increased to 140 gallons per minute, while the pressure indicated at the Burnside machine was 45 pounds per square inch, when the water was running.

The range of pipes by which the water was conducted from the machine was connected to the tap, N, 1½ inches in diameter, on the under side of the machine (Fig. 4, Plate IV.). The range consisted of 12 feet of pipes 2¼ inches in diameter, next the apparatus; 216 feet of pipes, 3 inches in diameter; and 2,100 feet of pipes, 4 inches in diameter: giving a total length of 2,328 feet.

On November 28th a second connection was made with the machine, by laying a range of pipes consisting of:—12 feet of pipes 1½ inches in diameter, and 216 feet of pipes 4 inches in diameter, and connecting it to the fore-end of the machine, and to the first range at the point where the pipes 3 inches and 4 inches respectively in diameter were connected together. The quantity of water, which had fallen to 108 gallons per minute was increased to 145 gallons, and the pressure which had already receded to

39 pounds, was further reduced to 28 pounds per square inch. The level of the water in the Harvey seam staple had lowered considerably by this date (Fig. 15, Plate V.).

As the water lowered down the staple, water-blasts were feared, but beyond the slow lowering of the water, which varied very much with the barometer, no change took place until January 24th, 1901, when the water was only 26 feet above the thill of the Harvey seam. At this date, a considerable quantity of gas began to be given off in the staple, with a faint rumbling noise, the surface of the water became disturbed. and the float, with which the level of the water was measured, rose and fell as much as 6 inches, 3 or 4 times a minute. On February 11th, 1901, the float reached some débris, 13 feet above the bottom of the staple; and on February 15th the rumbling noise was heard for the last time.

After the float reached the débris, it was still possible to obtain a fair idea as to the extent of the drainage of the Thornley workings by drawing a contour-line across the plan at a level corresponding to the pressure indicated at the Burnside apparatus, when the taps were turned off. This was done periodically until May 25th, 1901, at which date no pressure was indicated and the water-feeder had diminished to 35 gallons per minute, probably due to the feeders made in, and escaping down, the Thornley shaft and Harvey staple, together with a little drainage from the Harvey seam.

Previous to this, a final attempt had been made on May 21st 1901, to get more water by boring the hole further; the rods travelled 7 feet in soft material, and at a total length of 80 feet they again encountered a hard substance. This was followed by no increase of water.

On June 13th, 1901, the boring-apparatus was withdrawn, and a few days later the headways was again set away, the bore-holes being continued. Several more bore-holes were put through into the Thornley workings, and on July 11th, a coal-hewer holed into a narrow headways (Fig. 3, Plate III.). The headways was partially open at the holing, but it was quite close a few feet away. Very little gas was evolved, and very little air travelled in either direction through the holing.

The water, particularly when it first came away, had a dis-

tinctly soapy feeling and a sickly taste; and when first relieved from the pressure, it was white, but it quickly became clear, without any visible deposit being formed. The temporary whiteness was probably caused by gases escaping from solution, on account of the reduction of pressure. The water left a white slimy deposit, wherever it flowed, for a distance of about 360 feet from the pipe-end; beyond this point there was a thin red ochreous deposit for a short distance. There was no white deposit in the pipes, only a thin black scale, and no white deposit was found in the Thornley workings.

The water had a strong smell of sulphuretted hydrogen, and at the pipe-end a large quantity of gas issued with the water. There would probably be some methane, but the sulphuretted hydrogen was most prominent. The writer could devise no method of proving either the presence or absence of methane, as the action of sulphuretted hydrogen on a flame is similar to that of methane. The sulphuretted hydrogen was easily recognized by its odour, and by its action on test-papers impregnated with a solution of lead acetate and dried: these papers were quickly turned black when placed near the pipe-end. Sulphuretted hydrogen is the only gas that will turn lead acetate into lead sulphide.

Blue-litmus papers were turned of a reddish tint at the pipe-end.

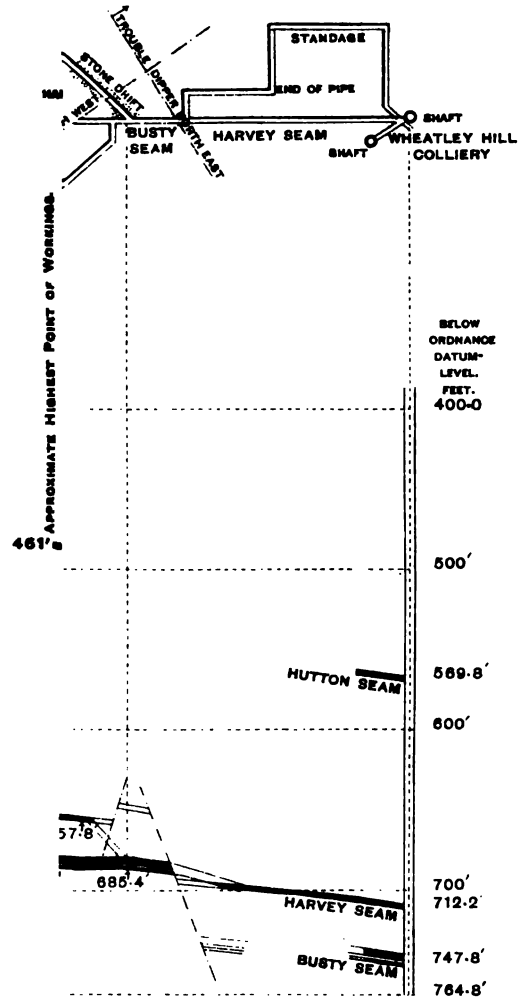
The cap produced on a Marsaut-lamp flame, at the pipe-end, was much more blue than the usual fire-damp cap. There was no dimming of the flame, as might have been expected had any carbon dioxide been present.

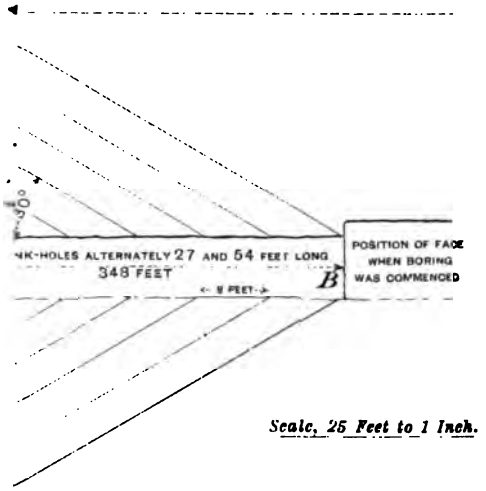
The white slimy deposit left by the water largely consisted of sulphur, precipitated through the sulphuretted hydrogen being partially oxidized by the air. This deposition of sulphur usually takes place when a solution of sulphuretted hydrogen in water is exposed to the air, and the water in flowing over the rough bottom would facilitate this action.

The water originally came partly from the workings in the Low Main seam of Thornley colliery, and some of these water-feeders are salt.

About 4 years ago, the writer exposed some lead-acetate test-papers at the top of the Harvey staple, and detected the presence of sulphuretted hydrogen.

*eatley Hill Colliery."* VOL. XXIII PLATE III



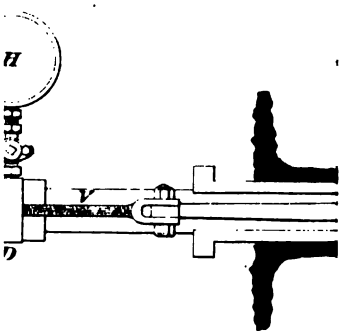

*Scale, 25 Feet to 1 Inch.*

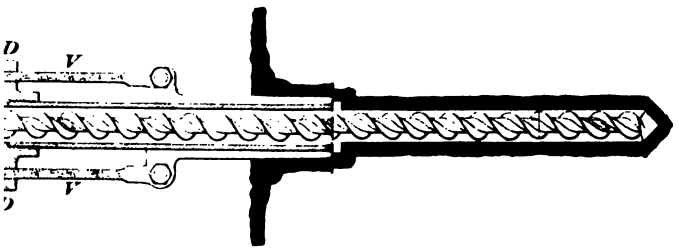
URNSIDE MACHINE AND
ERY.

*North* *VOL LI. PLATE III.*

3-MACHINE.

1 Foot to 1 Inch.



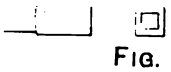



Fig. 11.

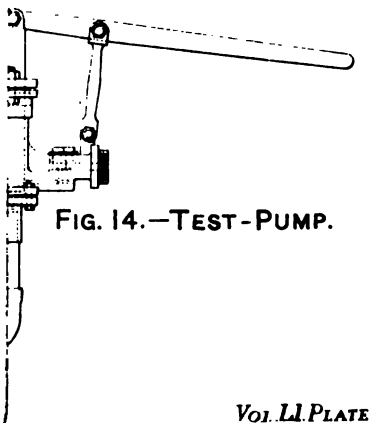
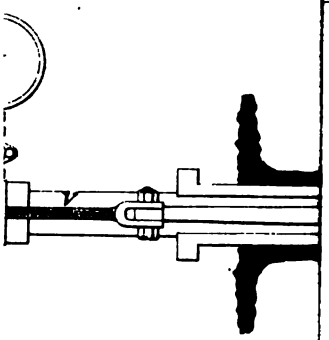


Fig. 14.—Test-Pump.

-MACHINE.

1 Foot to 1 Inch.



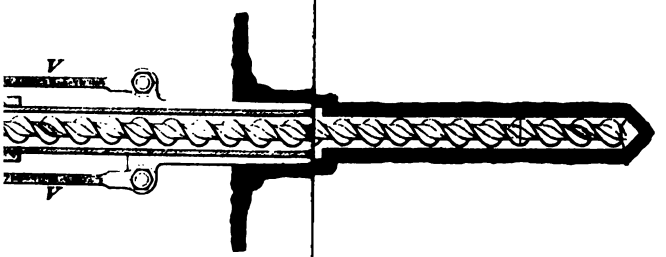


FIG. 11.

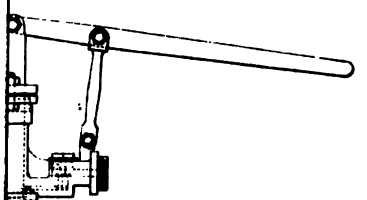
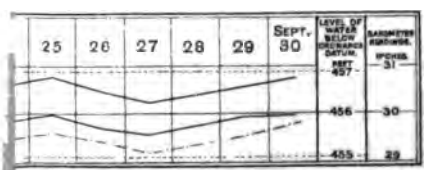


FIG. 14.—TEST-PUMP.

gs at Wheatley Hill Colliery."

COLLIERY, AND THE
INUTE RUNNING
MARCH 2ND, 1901.




APLE. DURING SEPTEMBER, 1884.

At times, with a low barometer, gas bubbled out of the water in the Harvey staple, but more usually the gas rose from its surface without any visible movement. The effect of the barometric pressure on the level of the water in the Harvey staple was very marked in the year 1884 as shewn in Fig 16 (Plate V.). On this diagram, the measurements of the water-levels are inverted and reduced in the ratio of the specific gravity of mercury to that of water, so as to give parallel results. Similar variations are also recognizable on Fig. 15 (Plate V.) though not so marked, as the scales are not suitable for shewing it, and there were other disturbing influences at that time.

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Mr. J. B. SIMPSON asked what was the actual distance driven and the head of water at the time of holing. He would also like to know whether the workings were holed into exactly at the position which the plans indicated.

Mr. W. B. WILSON, JUN., replied that the length driven was about 480 feet, when the drill-hole 67 feet long encountered the feeder of water, at a pressure of 85 pounds per square inch. It was not yet known whether the workings had holed exactly at the position indicated by the plans; the distance, however, was correct, but the workings might be somewhat out of position.

Mr. PHIL. KIRKUP remarked that one of the greatest difficulties with which he had had to contend in boring against water was that the machine became very much clogged when the hole was damp, but with running water there was no difficulty. He also asked whether in drilling holes, which were damp, the power required was such as to necessitate the use of a ratchet.

Mr. C. C. LEACH asked why the Burnside apparatus was adopted.

The PRESIDENT (Mr. J. G. Weeks) drew the attention of the writer to the statement that "some of the straight-on holes were continued as the face advanced, to a total length of more than 100 feet; 95 feet being the greatest length on any hole at any one time."* What did this mean?

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 77.

Mr. W. B. Wilson, jun., stated that trouble had been experienced from the rods clogging in the holes, and this was especially the case in damp holes. The Burnside apparatus was used in order to have control of whatever water was found, and they were afraid of encountering more water than they could deal with. He did not think that a ratchet had ever been used, in consequence of the hole being damp. There were always two men at the handle of the boring-machine, although the services of both were not always required, unless the hole was damp, or when drilling through unusually hard material. The greatest length on any hole at one time was 95 feet; the 100 feet referred to a straight-on hole, where the hewer was continually hewing off a certain length of hole. The same hole was extended on the following night; and the total length measured from where the hole was started exceeded 100 feet in several holes. The 95 feet hole was a flank hole, and it was extended to that length because it showed signs of water.

Mr. T. E. Forster stated that he had seen the Burnside apparatus in use in Hartley colliery, and it seemed to him to be a very efficient apparatus. He thought, however, that when a machine of this kind was adopted, it should be used in every hole from the commencement to the finish of the work. He thought that considerable risk was involved in allowing the man in charge to determine when the apparatus was to be used. At a colliery in Durham, where there had been an inundation resulting in the loss of several lives, until the pick was put through the coal into the water, there was not the slightest sign of any "bleeding."

Mr. R. A. S. Redmayne stated that the Burnside apparatus had been used in the exploration which had been made against the old Hartley workings. In that case, two men per shift were employed at the machine, and a deputy was placed with them in each shift as an extra precaution. The use of the Burnside appliance only slightly enhanced the cost of boring the holes. Occasionally there had been difficulty in setting the machine, and sometimes it was difficult to withdraw, if it were tightly fixed. The longest hole at Hartley was bored to a length of 63 feet. The same men were employed continuously at the machine, although the rest of the workmen objected and claimed that they should have a turn at this bargain, but it was very necessary that they should only employ the most practical and capable men. The same front

hole had been extended for 300 feet, and, except when the holes met with a "trouble," he did not think that they had once run into the top stone. Flank-holes were bored on both sides of the headings, every 6 feet, at an angle of 45 degrees and 25 degrees alternately, and for a distance of 30 feet. The front hole was kept 30 feet in advance of the face. There were no signs of water until they actually holed into the old workings with the drill: the head of water was 82½ pounds per square inch, and the workings were found within 1½ feet of their position on the plan.

Mr. W. C. BLACKETT stated that in the accident at Kelloe, where they holed into the workings of Old Cassop colliery, the pick holed through without any previous indication of water, and the deputy (who had an extraordinary adventure, being so long underground) saw nothing whatever to alarm him before the water broke away.

Mr. J. SOUTHERN said that he had experienced great difficulty in boring with rotating machines, and owing to the rods slurring up, the men were just able to bore about 5 feet per shift. The difficulty was overcome by the use of hollow rods, which enabled them without difficulty to bore 50 feet in a shift. He had also tried the Burnside apparatus; it was very safe and reliable, and there was very little waste of water coming through the plugs. The hole was driven 80 feet, and the pressure was 180 pounds to the square inch.

Mr. PHIL. KIRKUP understood that the usefulness of the Burnside apparatus was really one of safety, in so far that they were enabled to control the water when it was tapped. He asked whether an angle of 30 degrees from the line of the place was the best angle at which to drill the flank-holes.

Mr. R. A. S. REDMAYNE said that flank-holes should be arranged so that they almost cut each other, and that no place could come in between them.

The PRESIDENT (Mr. J. G. Weeks) said that the safety of a colliery sometimes depended on the way in which drowned-out workings were broached, and Mr. Wilson's paper would prove valuable to students as well as to those having charge of mines. The introduction of the Burnside appliance would give confidence

to the workers and secure additional safety; and where there was a heavy head of water, it should be adopted in and applied to all the bore-holes that were being made. These holes could probably have been drilled without any safety-appliance, but in certain positions, such as boring in a place to the "dip," if the workman lost his head he would probably lose the colliery as well, whereas with the Burnside apparatus he could turn a tap and attain security at once. The angle of the flank-holes and their distance apart from each other and their lengths must be left to the discretion of each manager; but he advocated the use of two straight-on holes, driven about 18 or 24 inches from each corner of an 8-feet or less place, instead of a single front hole, though each one should consider the question for himself. Care must be used so as to be as well protected on the flanks of the exploring-place as in the front of it. Cross-cuts and other ways could come in between the holes at different angles, and the bore-holes must be placed so that it would be impossible to miss such places. The smaller the width of an old working, the more likelihood there would be for the bore-holes to miss it, and in making calculations as to the angle of the bore-holes they should assume that the place into which they might hole might be only 5 feet wide. He had pleasure in proposing a hearty vote of thanks to the writer of the paper.

Mr. JOHN DAGLISH seconded the proposal, which was cordially adopted.

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Prof. HENRY LOUIS read the following paper on "Standardization of Surveyors' Chains."

# STANDARDIZATION OF SURVEYORS' CHAINS.

By Prof. HENRY LOUIS, M.A., A.R.S.M., etc.

It is perfectly well known that the ordinary surveyors' chain, at no time a very accurate measuring appliance, rapidly becomes inexact in use, so much so that if these inaccuracies are not constantly corrected, very serious errors may be introduced into surveys made with such chains. It is customary at important mines to lay down, once for all, a standard length, by which all chains may be adjusted. The object of the present brief communication is to draw attention to the various precautions that should be observed in setting out such a standard length and to detail those employed by the writer in laying down standard lengths of 66 feet and 100 feet respectively at the Durham College of Science. These latter standard lengths have been recently set out, and the Council of the College has authorized the writer to place them at the disposal of any surveyor in the district, who may wish to accurately adjust his chains.

*Standard Lengths.*—The standard lengths are marked by means of three small brass plates let into the concrete flooring of one of the College corridors. Concrete expands and contracts very little under change of temperature, and it is therefore especially suitable for this purpose; moreover, the corridor is kept at an approximately uniform temperature. The lengths of 66 feet and 100 feet are marked by means of fine and deep lines cut into the above-mentioned brass plates.

The measuring appliance used in setting out these marks was a standard steel tape, made by Messrs. Chesterman & Company, Limited, tested specially by the Standards Department of the Board of Trade, subsequently retested by the makers, and found to be absolutely accurate at a temperature of 62° Fahr., under a pull of 3 pounds, when the tape was supported throughout its length on a level surface.

The marks having been set out as accurately as possible with this tape, a series of observations were made at the above pull and at the standard temperature; the tape was left in the corridor for

some time in order to bring it to the temperature of the corridor, and the temperature was read by means of six thermometers placed at equal intervals along the tape, while the pull was determined by means of a spring-balance attached to one of the handles. The distance between the centres of the graduations on the tape and the centres of the marks in the brass plates was read by means of a magnifying glass on a standard steel rule divided to hundredths of in inch; and in this way the following errors were determined:—

I., 66 feet: too short by 0·06 inch.
II., 100 feet: too short by 0·04 inch.

Where extreme accuracy is desired for any reason, these corrections can be applied, but it is obvious that the standard lengths as laid down are accurate enough for all practical purposes.

It may be worth while to examine the effect of any deviation from the above standard conditions in respect of temperature, amount of pull, and mode of support of the tape.

*Effect of Temperature.*—The linear expansion of steel is about 0·000006 of its length for 1° Fahr.; hence a 100 foot steel tape will expand or contract 0·007 inch, and a 66 foot steel tape 0·005 inch, for a rise or fall in temperature of 1° Fahr. In this country it is rare for the temperature in a colliery to vary more than 20° either way from the standard temperature of 62° Fahr., hence if chains or tapes are adjusted at the standard temperature, any variation in length due to change of temperature on going underground may be disregarded. For very accurate work, it is, however, necessary that the standard length be set out under shelter, in a place that can be kept at a uniform temperature. For example, if a 66 foot chain were adjusted to the standard length in the open air at 32° Fahr., and then taken into a pit where the temperature was 82° Fahr., an error of ¼ inch per chain would be introduced unless the correction were applied. Even greater errors might occur, if the chain were standardized while exposed for any length of time to a strong summer's sun.

*Effect of Pull.*—The standard steel tape used in the above measurements was 0·375 inch wide and 0·014 inch thick, and weighed 0·016 pound per running foot. Three pieces of steel tape of similar material, supplied by the makers, but 0·5 inch

wide and 0·015 inch thick, and weighing 0·024 pound per running foot, were tested to destruction in the testing-machine. The actual results obtained are shewn in Fig. 1 (Plate VI.), and the average of the three closely concordant tests give a mean elongation of 0·122 per cent. for a pull of 0·1 ton, or 0·055 per cent. for a pull of 100 pounds, until the elastic limit was reached; this latter was about 0·63 ton, and the average breaking-strain was about 0·735 ton.

The standard steel tape was stretched on a level surface, definite pulls were applied to one end and measured by means of a spring-balance, and the elongation was recorded. The results of two such tests are shewn in Fig. 2 (Plate VI.), giving as an average result an extension of 0·01 inch for a pull of 1 pound, or 0·08 per cent. As the cross-section of this tape is 0·7 of the tape tested in the machine, the extensions should be in about the proportions actually found, namely, in the ratio of 10 to 7.

It is obvious that the amount of extension under an abnormally heavy pull is by no means to be disregarded in accurate surveys, as a pull of 50 pounds would cause an error equal to about 3½ links per mile, measured with the above tape.

*Effect of Supporting Tape.*—It has been stated that the tape must be evenly supported throughout its entire length. If a tape be made fast at one end and a definite pull be applied to the other, the tape will sag, forming a curve which will approximate very closely to a true catenary, and, owing to this curvature, the distance between the two ends of the tape will be less than its true length. The amount of shortening will depend upon three elements, namely:—The length of the tape, its weight and the pull upon it. Given the ratio that the pull in pounds bears to the weight of the tape, also expressed in pounds, the percentage of shortening (the length of the tape being taken as 100) can readily be calculated.

In Fig. 6 (Plate VI.) let a chain or tape ACB be attached to a point, A, and pulled, at B, with a tension equal to T pounds. Let the length of the chain be $l$ units (feet or links) and let its weight be W pounds. Call the length, AB, $x$ units, and the depth of sag $h$ units. Then the shortening $s$ will be equal to $l - x$, and the following equations represent the relations between these figures, with sufficient accuracy for practical purposes:—

$$s = \frac{l}{24}\left(\frac{W}{T}\right)^2 \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$h = \frac{l}{8}\frac{W}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

$$s = \frac{8}{3}\frac{h^2}{l} \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Whenever W/T is less than 1, as is generally the case, the above equations are practically true.

The same 100 foot tape was freely suspended under various pulls, and the difference between its true length and the length under these conditions was measured, the results obtained being recorded graphically in Fig. 3 (Plate VI.). Obviously, under these conditions, the tape is elongated by the pull upon it, while it also indicates a shortening owing to the amount of sag; at low pulls the latter figure is larger than the former, while at high pulls the opposite condition prevails. There is accordingly a pull at which these two errors must balance, and experiment shows that this was the case with a pull of about 21 pounds. In order to determine the shortening due to sag, the amount of lengthening must be allowed for; this has been done approximately, and the average results are also plotted in Fig. 3, in which the calculated shortening is also laid down. It will be noticed that the observed shortening is somewhat less than the calculated, the discrepancy being fairly constant, and this is probably due to slight errors both in the mode of suspension and in the spring-balance employed.

*Measuring by Means of the Chain.*—What has been said about tapes applies equally to chains; it is hence clear that, even with a correctly adjusted chain, errors may be introduced unless the chain is used in surveying under precisely the same conditions as in standardizing. The co-efficient of expansion or contraction of an ordinary surveyors' iron chain under varying temperatures may be taken as identical with that of a steel tape, and it has already been pointed out that this influence of temperature may, for practical purposes, be disregarded; it remains, therefore, to investigate the effect upon an ordinary chain of the two other elements, namely, the extension under pull, and the result of sag due to the chain not resting upon the ground.

*Extensibility.*—A 100 foot galvanized-steel chain, made of wire 0·155 inch in diameter, weighing 10¼ pounds, with links not brazed but simply closed in the usual way, was tested under different pulls when resting upon the ground. The results of three such tests are recorded graphically in Fig. 4 (Plate VI.). It will be noticed that the extension is by no means uniform, and that there is a certain amount of discrepancy between the several experiments, the chain not always returning quite to its original length when the strain was removed. The average extension seems to be about 0·026 inch for 1 pound of pull, or 0·22 per cent. for a pull of 100 pounds. This is evidently enough to cause perceptible errors with a heavy pull in chaining a long line. Thus, under a pull of 50 pounds, the above chain would give a measurement 5 feet 9 inches short in 1 mile.

It is well known that chains generally become permanently longer by use, probably not so much owing to the actual stretching of the metal as by slight opening, under wear, of the numerous links of which it is composed. Thus the four chains in use at the Durham College of Science (where the wear is much lighter than it would be at any ordinary colliery) were tested under a pull of 10 pounds, with the following results:—

| No. | Description of Chain. | Weight in Pounds. | Too long. Inches. |
|---|---|---|---|
| I. | 100 feet galvanised steel ... ... ... ... | 10¼ | 0·75 |
| II. | 100 feet light steel ... ... ... ... ... | 4¾ | 7·70 |
| III. | 66 feet brass ... ... ... ... ... | 9 | 3·15 |
| IV. | 66 feet steel ... ... ... ... ... | 8¼ | 3·45 |

Chain I. was found to be 2·25 inches too long at the 66 foot mark.

*Effect of Sag.*—Owing to the much greater weight of chains than of tapes, the shortening due to sag is much more pronounced. As already shewn, its amount can easily be calculated; in order to avoid even the trouble involved in this calculation, Fig. 5 (Plate VI.) has been prepared, from which the percentage of shortening caused by any given pull upon a chain of any given weight can be found by simple inspection. Thus, if a chain weights 8 pounds, and is used freely suspended, with a pull of 16 pounds: the coefficient of the weight of the chain divided by the pull is $\frac{8}{16}$ or 0·5; from Fig. 5 the percentage of shortening corresponding to 0·5 is seen to be just about 1·05 per cent., or say 1 link to the chain, so that a distance measured under these

conditions would be found to be 84 links in the mile too long, unless the proper correction were applied. It is obvious that if a uniform pull be applied, quite as accurate results can be obtained with the chain or tape always freely suspended, the end-marks being obtained by means of plumb-bobs, if the proper correction for shortening is applied. This method is often used abroad, and occasionally in this country, for instance, in "stepping" a slope or in chaining along a level deep in mud. It is only necessary to determine what is the proper amount of correction to apply. This may be done either by keeping the pull about uniform, which chainmen can readily be taught to do, or using a spring-balance attached to one of the handles where special accuracy is required, or else by measuring the amount of sag with a foot-rule. From Fig. 5 (Plate VI.) the amount of shortening as indicated by the third equation, corresponding to any given sag, can be obtained by simple inspection. What is obviously inaccurate is the practice, that often obtains, of using the chain indifferently either lying on the ground or freely suspended, without applying any correction.

*Conclusions.*—Unless the corrections here referred to are applied, it is evident that the surveyor's chain must be an even more unreliable instrument than it need be owing to the inherent defects of its mode of construction. In the writer's opinion it is only suitable for rough work, and to be used in conjunction with the miner's dial, which is probably about on a par with it as regards exactitude. Where the nature of the work is such that a theodolite needs to be employed, an accurate steel tape should replace the chain. No doubt in the vast majority of cases, these refinements of accuracy are not needed; but every now and then cases will occur, where the corrections discussed in this paper may be applied with advantage.

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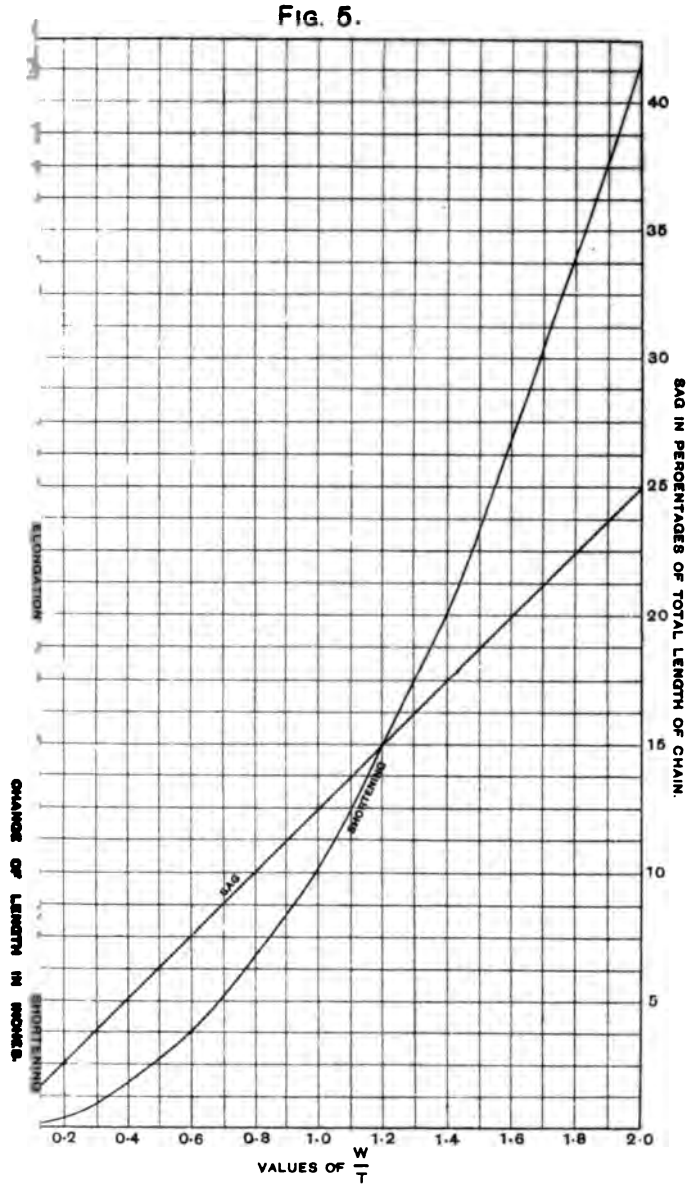
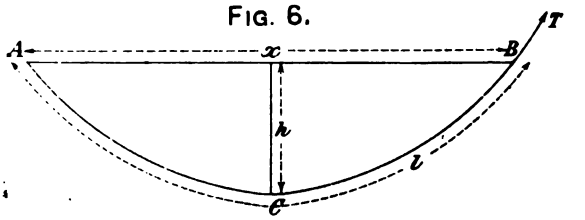
Mr. C. C. LEACH said that Prof. Louis' paper was of great value as it directed attention to the fact that correct measuring was the most difficult part of surveying, and the greatest difficulty was in ascertaining the exact length. Prof. Louis had referred to vertical sag, but horizontal sag was also a common source of error, and sufficient care was not always taken to straighten the chain

FIG. 5.




IRAM OF SHORTENING AND SAG CORRESPONDING TO DIFFERENT VALUES OF $\frac{W}{T}\left(\frac{\text{WEIGHT OF CHAIN}}{\text{PULL}}\right)$

FIG. 6.



properly. Again, links were apt to overlap each other, and that also would shorten the chain. Another source of considerable error was the stretching of the chain by rough handling and tugging when it became fastened or was trodden on. He hoped that Prof. Louis would mark every tenth link of his standard chain-length at the Durham College of Science.

Mr. R. A. S. REDMAYNE said that the moral of Prof. Louis' paper was that the theodolite and the tape should be used for accurate surveys, and for all filling in of details they could use the miners' dial and the chain, and he thought that this was the system generally practised by those who strove after accuracy. The members were indebted to Prof. Louis for obtaining for them such an admirable place for testing chains and tapes as that afforded by the Durham College of Science, and no doubt many of the members would take advantage of it.

Mr. J. KENNETH GUTHRIE endorsed the necessity for standardizing surveyor-chains. He had tested a chain recently, it was only two years old, and he found that it was about two links too long.

Mr. W. C. BLACKETT asked whether it would not be practicable, in making rough underground surveys of considerable length, to use a light steel rope, with which they could measure the number of chains, and the reading of the links could be made with the chain. He did not think that the steel-rope would have worse properties, as regards shrinking and stretching, than the ordinary chain.

Mr. C. C. LEACH said that he had long ago discarded the chain in favour of the steel tape. In the Ordnance Survey of Great Britain very great care was taken in measuring the base-line on Salisbury plain, it was done with glass rods and it took about 3 years to measure a length of 3 miles.

Prof. H. LOUIS said that the horizontal error in practice was often very serious, but in his paper he had assumed that the chain was being used with every possible care, under which condition horizontal error could be entirely avoided. For example, it was avoidable under fairly heavy pulls, though he was quite sure that it played a very important part in errors of surveying. He had,

after giving the matter considerable attention, come to the conclusion that wire-rope was quite unsuitable as a measuring instrument: it was wound necessarily in spirals, and it had therefore too much elasticity. In surface-surveying in Australia, and for underground surveys in America, a steel wire was employed. A little brass ring was brazed on the steel wire at every tenth link, and a little nick was made to indicate the exact centre. The surveyor also carried a steel tape with which he measured accurately from the last nick to the point surveyed to.

The PRESIDENT (Mr. J. G. Weeks), in moving a vote of thanks to Prof. Louis for his paper, said that it was very useful for the members to know exactly what they were doing when making measurements, as accuracy was so very important. Many years ago, he had measured a length on his granary-floor for the purpose of testing the surveying chains, though he might possibly be told now that measurement on a cement floor would be preferred, as being less liable to expansion or contraction. The suggestion that every tenth link should be marked on the standard length by which the chains were tested was perhaps one which Prof. Louis could see his way to have adopted at the Durham College of Science.

Mr. C. C. LEACH seconded the vote of thanks, which was cordially adopted.

Mr. W. C. BLACKETT, referring to the question of expansion or contraction mentioned by the President, said that it might possibly be better to have a test-measurement marked on some material which would be subject to the same variations from temperature as the chain itself.

Mr. BENNETT H. BROUGH (London) thought that by laying down standard lengths at the Durham College of Science, Prof. Louis had conferred a great benefit upon surveyors in the district, to whom the standard laid down by the Board of Trade on the north side of Trafalgar Square, London, was inaccessible. The conclusion to be drawn from the author's painstaking investigation was undoubtedly that when a theodolite was used the chain should be replaced by the steel tape. At the same time, the chain was so convenient, so safe in unpractised hands, and had given such good results in filling in details of the Ordnance Survey, that for

many purposes it could ill be spared. The corrections arrived at by the author with a view to rendering the chain more trustworthy were consequently most welcome. The need for standardization had long been recognized. Even in 1570, the German surveyor, Jacob Koebel, described a primitive method of standardization somewhat as follows: "A rood should by the right and lawful way, and in accordance with scientific usage be made thus: Sixteen men, short and tall, one after the other, as they come out of church, should place their left shoes in a line and if you take a length of exactly 16 of these shoes, that length shall be a true rood, with which you may measure fields." It was interesting to compare this quaint method with the author's delicate operations. On the Ordnance Survey, chains had to be compared with the standard every morning, and a line with an error of 2 links in 1,000 was passed. At one time on the Ordnance Survey, chains were solely used, and were stretched in wooden trays between a drawing-post and a weight-post with a pull of 56 pounds. In the Continental mining-schools, the testing of 20 metres chains was conducted by a method somewhat similar to that adopted by the author. On a solid concrete level surface, an iron post was fixed, upon which one end of the chain was placed, while the other end was attached to a wire running over a pulley and loaded with a weight of 10 pounds. At a distance of about 20 metres (the length of the chain), a metal plate graduated in millimetres was let into the floor, and on that could be read with accuracy the division to which the end of the chain reached. Chains were made in which the central link was so constructed that a correction of the chain might be effected by the aid of a right-handed and a left-handed screw. With such chains, used in conjunction with a spring-balance recommended by the author, results of considerable accuracy should be obtained. The spring-balance devised in 1901 by Mr. M. Przyborski* would appear to be well adapted for the purpose.

Prof. H. Louis agreed entirely with Mr. Brough's views, although he would not like to endorse without qualification the statement that the chain was safe in unpractised hands; he had known—and no doubt Mr. Brough had also known—surprisingly

* *A Treatise on Mine Surveying*, by Mr. Bennett H. Brough, ninth edition, 1902, page 25.

divergent results obtained by beginners in chaining. As the practical work of chaining had been so often mentioned in the discussion, he would like to draw attention to an error that did not come within the scope of his paper, but that might be worth mentioning, namely, the error due to the thickness of the pin in chaining a long line. This could be entirely avoided by the plan, often adopted by continental makers, of notching each handle with a notch equal in depth to the radius of the pin. He recommended this simple plan and was surprised that it was not universally adopted.*

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## AWARDS FOR PAPERS.

The SECRETARY read the following list of papers, communicated during the year 1900-1901, for which prizes of books had been awarded by the Council to the authors:—

"The Solvent Action of Pyridine on Certain Coals." By Mr. T. Baker, B.Sc.

"Endless-rope Haulage at Axwell Park Colliery." By Mr. R. W. Glass, Stud.I.M.E.

"Some Silver-bearing Veins of Mexico." By Mr. Edward Halse, M.I.M.E.

"Dry and Wet Treatment of Copper-ores." By Capt. C. C. Longridge, M.I.M.E.

"The Employment of Iron Bars at the No. 6 Pit, Lens Colliery." By Mr. E. Reumaux.

"A Method of Boring Deposits out of Rising-main Pipes in Shafts." By Mr. Hugh Ross, M.I.M.E.

"A Flash of Lightning at the Lambton Colliery, D and Lady Ann Pits, on October 2nd, 1900." By Mr. Jacob Sharp, M.I.M.E.

"Safety-lamp Cabin at Heworth Colliery." By Mr. Thomas V. Simpson, Stud.I.M.E.

"Sinking through Swamp, Clay and Sand." By Mr. William Tattley, M.I.M.E.

"Endless-rope Haulage at Pelton Colliery." By Mr. Norman M. Thornton, Stud.I.M.E.

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* He would like to draw attention to the fact that a paper was read at the students' meeting of the Institution of Civil Engineers, on March 14th, 1902, by Mr. H. J. Deane, on "The Use of Long Steel Wires in Surveying," which appeared to cover some of the ground which he himself had covered in his own paper.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, MARCH 10TH, 1902.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBERS—

Mr. L. NEWTON, Surveyor, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.
Mr. E. J. SANER, Fenton Engineering Works, Stoke-upon-Trent.
Mr. E. E. V. Stokes, H.M. Inspector of Mines, Stoke-upon-Trent.

ASSOCIATE—

Mr. HARRY MITCHESON, Florence Colliery, Longton.

STUDENT—

Mr. DACRE CROUDACK, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.

Mr. R. W. CLARKE read the following paper on "Coal-cutting by Machinery":—

# COAL-CUTTING BY MACHINERY.

By R. W. CLARKE.

The subject of coal-cutting by machinery, which has become of increasing importance during the last few years, has been exhaustively dealt with and discussed, but there are undoubtedly still many points in connection with the matter, which have hardly received sufficient attention.

*Motive Power.*—The first important point to be considered is that of the power to be adopted for driving the machines. It will no doubt be conceded that, where the mine conditions are suitable, electricity possesses great advantages over compressed air. A few of these advantages may be enumerated as follows:—(1) Less initial outlay for generating plant. (2) Cables, compared with pipes, are cheaper, cost less to lay, take up less room, and are easier to maintain. (3) Efficiency as between the prime-mover and the motor. With regard to this point, which is all important, electricity from the very start is the most economical agent, and as the working-faces advance farther away from the shaft, the percentage of efficiency becomes more marked as compared with compressed air.

*Type of Machine.*—The next point to be considered is the type of machine that should be employed. In recent papers dealing with this subject, an attempt has been made to suggest a perfect type of machine to deal with the varying conditions of the coal-face. The writer, however, is of opinion that it is impossible to design a so-called perfect machine, and that types must be multiplied and modified to suit different collieries. For instance, in a thin seam, it will perhaps be necessary to employ a machine to develop say 20 horsepower, weighing not more than 30 cwts., with a maximum height above the floor of 20 inches. This machine will probably give excellent results in a seam, 2 feet thick, where the coal need not be undercut to a greater depth than 3½ feet.

It would, however, be scarcely the type of machine for use in a seam 6 feet thick, where the coal must be holed to a depth of 5½ feet. In order to provide for the additional horsepower required, the machine must necessarily be bulkier and stronger, but in a thick seam, the additional weight will not be so a serious drawback.

It is a moot point whether the disc or bar is the best tool for undercutting. The writer does not propose to discuss the advantages of either method, but as the former has been the most successful, and has been more generally adopted in this country, it will be understood that this paper treats of coal-cutting with a disc-machine.

*Working-face.*—Perhaps the most important point, in connection with coal-cutting, is the face of coal, in which the machine will have to work; and there is no doubt that many machines have failed to give satisfactory results, not so much from the faulty design of the machines, but from the fact that it would have been next to impossible for any machine to do satisfactory work under conditions such as obtain in some mines. Many colliery-officials are intensely conservative, and refuse to believe that any modification of their methods is either possible or necessary. It should always be remembered that a coal-cutter is unlike any other mechanical tool: and that it is not fixed *in situ* like a lathe, coal-crusher or a drill, but has to travel along what must necessarily be a bad road, and is liable at any moment to be derailed or buried.

A little care and attention to such matters as straightening the working-face, setting the timber evenly, and providing good roads, laid with permanent rails, along which the machine has to be flitted, will often reduce the price of cutting in the most surprising manner.

There are two methods of laying out faces for coal-cutting. One may be called the long face, and the other the short face:-

*Long-face Method.*—The most perfect face consists of four sides of a square, the machine cutting continuously round and round without requiring to be flitted. This method is only practicable, however, in a seam nearly level, and free from water. Unfortunately these conditions seldom exist, and it is rarely possible to lay out a face in this manner.

It is, however, often practicable to adopt a modification of this plan by cutting two sides of a square. The machine starts from a wheel-hole at the bottom corner of the end-face, and after cutting the first side, is twisted at right angles and then proceeds to cut along the bord-face. It will be found a great convenience to keep a heading, 9 feet wide, in the corner, about 9 feet in advance. This will enable the machine to cut right through the end-face, leaving no coal to be holed off, while the heading always provides a wheel-hole for starting the machine along the bord-face. It must be remembered that when cutting towards the fast-end of a face, no machine can cut absolutely up to the post, and there always remains from 5 to 6 feet of coal to be holed by hand. The heading driven at an angle of 45 degrees to the end-face, however, will overcome this difficulty.

Where it is found impossible to lay out two faces at right angles to each other, good results may be obtained by laying out faces in a straight line and flitting the machine back to the starting-end along the main road, after it has cut through the face.

It is difficult to lay down hard-and-fast rules for determining the length of the face, but it may be taken that this length need only be limited by the difficulty of maintaining a proper haulage-road, along the level, parallel to the face; while it has been found by experience that 300 feet is the least economical length of face which can be worked on the long-face method.

At the Lidgett colliery, in South Yorkshire, one machine-face is 4,500 feet long in a straight line. The seam is 24 inches thick, 10 inches of inferior coal being taken up in the face to provide height and material for packing the waste. Two machines follow each other at regular intervals, each working 15 shifts per week, and the pack-walls are moved forward, on an average, twice in ten days. The gate-roads are spaced at intervals of 66 feet, and are cut off at intervals of 600 feet by cross-gateways branching right and left from main-gateways, 750 feet apart, which are ripped to make height for horses. When a new cross-gateway is started from the main-gateway, the pass-bye is moved to the new cross-gateway, and the horse or any other method of traction receives the coal at the new passbye.

*Short-face Method.*—This method, which has been largely adopted in Scotland, consists of laying-out faces of such a length

that the cutting and filling can be performed in a certain length of time, say 24 hours. The machine, on finishing its cut, is not flitted back to the starting-end, but, when the face has been cleared of coal, cuts back again along the face to the right-hand corner.

The length of the face and the distance of the gateways from each other is determined by the thickness of the seam; but it may be stated that lengths of 300 feet with gateways 45 feet apart have given good results, the face being moved in some cases 5 times per week.

It is possible by this method to obtain good results, but only by the most unremitting attention on the part of the management. Any loss of time on the part of the workmen, or breakdown of the machine, will entail the dislocation of the system, and the loss of the output from that particular face for the day on which the breakdown occurs. With regard to labour, the difficulty can be met by adopting the butty system as practised in North Staffordshire; and breakdowns of the machine can be guarded against by stocking spare parts, which are accessible to the machine-men at any hour of the day or night.

*Reversing the Machine.*—With regard to the question of cutting backwards and forwards, a great deal of skill has been displayed in attempts to design a machine which will cut equally well in either direction. In the writer's opinion this is misdirected energy, as it is practically impossible for any machine to cut equally well in either direction. The hauling-gear and the starting-switch must necessarily be respectively at the front and rear-end of the machine, if the machine is to be operated by two men, and if the machine is reversed, they will occupy positions which will make the work very inconvenient. The driver of the machine, who operates the switch at the rear, is in the best possible position for controlling the machine. His duties are to stop and start the machine, shovel away the holings, replace any road-packing which may have been misplaced by vibration or thrust, pull forward the face-cables from time to time, and pull up the last length of rails, when the machine has crossed them. If from any cause the wheel is rising or falling in the cut, or the machine is not making its full cut, he can, from his position at the rear, detect it at once and inform his road-layer.

If, in order to make the return journey, the motor is simply reversed, he will be able to do nothing but stop and start the

machine, and will require two assistants to do the work that one should do, namely:—Lay and pull up the road; while it will be difficult to clear away effectually the holings from the wheel, and the machine, if cutting near the floor, will either be completely choked or will absorb a great deal more current than is necessary. The haulage-rope also will pass under the machine, and with an undulating face will add to the danger of derailment.

The best method of overcoming these difficulties is to turn the machine completely round, and make the return journey with the wheel on the opposite side of the frame. The machine can easily be arranged for this by boring the frame on either side to receive the wheel-bracket and the carriages for the haulage-gear, while the shafts with their pinions need only be turned over, the whole operation taking about two hours. With regard to the twisting of the machine, many colliery-officials will say that they cannot afford sufficient room in the face to do this.

It must be remembered that when the machine has cut through, it will be impossible, in any case, for it to remain there. It must be moved somewhere to enable the last 6 feet of coal to be holed off and filled out. In such a face as we are considering, there is sure to be a gateway within a few feet of the cutting-out end; and the machine must be removed into this till the coal is cleared away. When it is taken back into the face, it must be twisted with the drum-end to the right hand and then shunted back into the corner, and it will then have been reversed without any large space being necessary, just as a locomotive is reversed on a triangle, in the absence of a turn-table.

*Difficulties.*—The writer has observed that, at some collieries, the management are willing to entrust the driving of their machines to men with the very slightest previous experience of such work, on the ground that they are cheap. It need scarcely be remarked that this practice rarely results in successful coal-cutting.

When a machine is cutting well in a favourable seam, the operation seems simplicity itself, and after the machine has been working for a short time, many have been heard to express the opinion that there is no difficulty in coal-cutting.

In order to correct this idea, the writer will endeavour to enumerate a few of the difficulties which may arise, and how to

overcome them. In the first place, it is essential that the machine should run on a firm stable road. The rails should be strong enough to bear the weight and thrust of the machine without bending; they should be of sufficient length to avoid too frequent joints, and yet be sufficiently portable to be handled by one man, and short enough to follow the undulations of the face in order to keep the machine up to the cut. A flat-bottomed rail, 12 feet long, with a section of 26 pounds to the yard, has been found to answer these requirements. The sleepers should be spaced about 4½ feet apart, and should be capable of being easily fixed and detached from the rails. The joint-sleepers should be of such a design as to prevent the rail-ends from moving in any direction, after they are adjusted; and it should be possible to adjust them to the rails when either rail is several inches in advance, which must inevitably occur in a face which is not quite straight or which is laid out on a curve. If, owing to the latter cause, either rail leads too far to allow the joint-sleeper to be fixed, the difficulty may be got over by spragging the last joint-sleeper against the machine, while the latter is in motion, and making it shove forward either rail; or by cutting off a few inches from the end of one rail, and using it to correct the lead at either side, when that becomes necessary.

As the thrust of the disc-machine operates away from the face at the rear-end, and towards the face at the front-end of the machine, packing must be inserted at either end of the sleepers, care being taken that the packing on the face-side is not high enough to catch the cutters in the wheel. If the face is not very straight, it may be advisable to dispense with packing on the face-side so that the machine may draw itself into the face and make a full cut. The goaf-side packing may then be put in, after the machine has drawn itself into the face. With regard to the latter, its efficiency will depend on the amount of timber available in the face, and the ingenuity and resource of the road-layers; but it is important to remember that the packing should be of such a nature as not to become displaced or drop down when the tension is relieved by the thrust of the front-end of the machine.

The rails may be either laid horizontally or inclined in any direction, but it is important that they should be solidly bedded on the floor. If this is not attended to they will tilt or sink, when the weight of the machine comes on to them, with the result that the cutter-wheel will either climb up or down. This is a very

disconcerting incident to the amateur coal-cutter, but can be corrected in a very short time by putting cutters into the wheel, either slightly turned down or up. When the wheel has resumed its normal position, the original cutters should be at once replaced. When climbing, the machine will of course ride above the rails carrying all its weight on the cutter-wheel, but the rails must not be raised up to the machine, as the turned-down cutters will inevitably bring it down within a few feet.

When approaching a crooked joint, the road-layer must attend at the front-end of the machine, and keep the front-bridle or thrust-arm quite slack till the joint is passed. He must then keep screwing it tight, till the rear rolling-wheel and bridle of the machine have crossed it. Neglect of these precautions will inevitably cause derailment at the front or both ends of the machine, which may mean a loss of between 1 and 3 hours.

*Workmen.*—From the above remarks, it will be seen that the driver of the machine should be a person of considerable intelligence and resource. He should first of all be a thoroughly competent miner, to enable him to take care of himself when the machine is running under bad roof. He should also have a rough working knowledge of elementary electricity and mechanics, to enable him to replace broken parts, to make ordinary electrical connections on the machine, and to adjust the brush-gear.

As a good driver can under favourable circumstances hole from 200 to 300 feet per shift of 8 hours with the assistance of a competent road-layer, turning out from 50 to 300 tons according to the thickness of the seam, it will be apparent that a colliery-manager having secured an individual of this description should treat him liberally in the matter of wages.

The Lidgett colliery management, mentioned above, employ upwards of ten machines to cut their weekly output of 3,500 tons from a seam 2 feet thick. About fifty men are required to man the machines, but a large reserve of men is maintained at the colliery. These men, it is needless to say, have all been trained at Lidgett colliery.

The writer must apologize for the length of this paper, but he has endeavoured to present the practical side of coal-cutting by machinery, in as small a compass as is compatible with the importance of the subject.

The PRESIDENT (Mr. W. N. Atkinson) remarked that the subject of coal-cutting was attracting attention at the present time, and was one to which mining-engineers would have to devote more attention in the near future. There seemed to be very little doubt that coal-cutting was a subject that would have to be taken up in this country to a greater extent than it had been up to the present time. America seemed to be the country where mining-engineers had gone into this question most extensively. Whether it was due to the machines or other circumstances, there was no doubt that the output of coal in the United States had increased so rapidly within the last few years as to make those States the leading coal-producing country of the world. In 1899, the number and kinds of machines in use in America* were as follows:—Total number of machines in use, 3,125, divided into chain, percussive and long-wall. Of the chain-machines, 564 were of the Jeffrey type, 95 link-belt, 401 Morgan-Gardners, and 46 others; of percussive machines, 590 were Ingersoll-Sergeant, 317 Sullivan, 992 Harrison, and 98 other systems: and longwall machines 22, making 3,125. The proportion of coal cut by machinery in America was about 25 per cent. of the total output, while in this country it was only about 2 per cent., so that there was evidently a great margin for the further use of coal-cutting machinery in Great Britain. Seeing that coal-getting was of so expensive and laborious a nature, it appeared rather extraordinary that the use of machinery had not been brought to a greater state of perfection before now. No doubt the difficulties were great, but if mechanical engineers received encouragement from colliery-owners they would make machines, and bring them to a greater state of perfection than they had at the present time.

Mr. A. M. HENSHAW said that the time had come when attention must be paid to the question of getting coal by machinery. There was no doubt that if mining-engineers applied themselves to the question of coal-cutting by machinery, many of the difficulties peculiar to this coal-field might be overcome. In the United States, the usual method of getting coal was by the old pillar-and-stall system: wide roadways were driven with long pillars, and a large percentage of coal was lost. American machinery was not suitable for working coal, particularly by the longwall system, in

* *Mines and Quarries: General Report and Statistics for 1900*, page 452.

this country, as a general rule. The difficulty of applying machinery in North Staffordshire arose from the steepness of many of the seams and the number of faults encountered; and he did not think that any machine was suitable for the majority of the North Staffordshire mines. The disc-machine was scarcely applicable to steep seams, or where faults were numerous. Steepness of the seam often meant badness of roof, and a disc-machine would only run a short distance before it encountered a feeble or bad roof, or coal so tender that it fell when the machine was at work. This difficulty was serious, as it not only meant danger to, or breakage of, the machine, but also stoppage of labour till the end of the shift, during which time no coal-cutting was proceeding. He believed that in one extensive colliery in Germany nearly the whole of the coal was wrought by machinery of British manufacture. He had recently seen, in a Lancashire colliery, a seam, 21 inches thick, cut for a length varying from 250 to 300 feet in a shift, and the cost of the coal delivered at the pit-bank compared favourably with the Arley mine, one of the standard seams. The use of coal-cutting machines was accompanied by an advantage, which must not be overlooked, because they might obviate a dangerous operation in coal-mining—the danger of shot-firing. He had seen coal got without shot-firing, where the coal was cut by hand, by the use of the Tonge hydraulic wedge or coal-getter. He had seen the same machine in operation, following the work of a coal-cutting machine, and taking down about 225 feet in a shift. Mr. Clarke had referred to some of the difficulties accompanying the use of coal-cutting machines generally, including the danger of a breakdown, and insisting on the necessity of additional supervision. He knew that these difficulties were operating against the introduction of coal-cutting machines, more than any other thing. He agreed with Mr. Clarke that unless skilled, trained men were set to work the machine, it would result in throwing out the machine, where a little skill and perseverance would be attended with success. He thought that electricity was the ideal motive power, and although good work was being done with compressed air, electric power was more portable. At the same time, there was considerable danger attending the use of electrical machinery in the mines of the North Staffordshire district. Electricity should not be used in the neighbourhood of gas, and he would hesitate to introduce electrical machinery in mines where naked lights were not allowed.

Mr. E. B. WAIN asked for information as to the cost of cutting coal by the machine that had been described in the paper. He had had no experience of the working of a coal-cutting machine, but he had had opportunities from time to time of knowing the working cost of a colliery where a coal-cutting machine had been largely used, and he had come to the conclusion that there was no marked saving in cost by cutting coal by machinery. The advantage, which was even greater than saving a few pence in cost of working, however, was due to the decreased percentage of small coal. When they considered the difference of price realized by round as compared with small coal, it would be understood what a difference there would be in the profit if the proportion of small coal could be reduced. Coal-cutting machines were subject to very rough treatment, owing to the difficulty of getting suitable men to work them. One of the pioneers of coal-cutting machinery told him that he had found a machine running in a colliery in Yorkshire, with some of its bearings red hot, owing to want of lubrication, and the workman in charge did not posses an oil-can. There seemed to be a " bogey " about a coal-cutting machine, and as soon as a man got used to working it, he became tired of the job. He agreed with Mr. Henshaw that bad roofs would affect the working of coal-cutting machinery. He (Mr. Wain) was of opinion that some of the bad roofs would become good roofs, if they were more regularly worked, and if a fall of coal was obtained through the working-place every two or three days, instead of once in two or three weeks, as was often the case in long stalls. An ideal roof for a coal-cutter would be one that did not require timber on the cutting side. He should like to know which was the best position for the cut, either close to the floor or some distance up the seam; and the most suitable machine for cutting close to the floor, or at a little distance from it. He would like to know what was the steepest gradient on which a coal-cutting machine could be worked. He thought that the plan advocated by the writer of the paper of cutting on two sides of a square, or better still two sides of a trapezium, was particularly suitable for seams lying at an angle of 15 to 16 degrees. An ideal arrangement for longwall working in such seams was to have the working-face only a few feet above the level at the inbye-end, and rising in one continuous line towards the outbye-end. Where workings were so laid out, the machine might be started at

the inbye-breasting end, cut to the corner, then along the whole length of face to the highest point at the outbye-end, lowered down the longest jigbrow and returned on the level to start again at the inbye breasting-end. He saw no difficulty in laying out workings in the seams on the eastern side of the North Staffordshire coal-field to suit such a plan, which would ensure systematic working under the best possible conditions.

Mr. R. W. Clarke explained that the machine must be set according to the circumstances of each seam: the roof, floor, and other matters having to be considered. He had trained many workmen, and found that if he got an intelligent collier, he could soon train him to be an efficient worker of the machine.

Mr. G. A. Mitcheson said that, listening to Mr. Clarke, who was an expert in the matter, it seemed comparatively easy to cut coal by machinery; but in his opinion there were several great difficulties to be overcome. There was no ideal coal-cutting machine, and he was convinced from what he had seen, that a machine might be capable of working well at one colliery and prove unsuccessful at another. There were, no doubt, collieries where coal could be cut by a machine, but it would cost more to get than by hand, if they could get plenty of colliers: because a collier could adapt himself to the circumstances of a mine better than a machine. Everyone who adopted coal-cutting machinery must be prepared for a revolution in the management of the mine. It meant a systematic method of timbering; or a system of timbering for the machine; or timbering that would render the mine safer from falls. With such roofs as they had in North Staffordshire, it was not desirable to multiply the number of gateways or jigs, and they put as few as possible where working by hand; but where they put in machines, the number of gateways must be increased. It was correct in theory to work the machine round the two sides of a square, but he could not see how it was to be done in practice. Another question was whether the coal would stand while the machine was holing. Again, when the seam was undercut to a depth of 5 feet, it did not necessarily follow that the coal was ready for the loader: he had seen coal holed by machinery, which was very difficult to get. The adoption of machinery for cutting coal would necessitate great alteration in the methods of working mines in the North Staffordshire district.

He agreed with Mr. Clarke that the best man to work the machine was an intelligent collier, because a skilled mechanic had not been trained in the mine to understand the difficulties of the roof. Although Mr. Clarke might have been successful in training these men in Yorkshire, still in commencing in another district some difficulty would be found in getting suitable men. The workmen were also looking after their own interests and trying to minimize the value of the machines, and some of them were willing to have the holing made by machinery if they received the same tonnage-rate for filling the coal. There was no doubt that the machine produced a greater percentage of round coal than hand labour, and this was the chief advantage of using the machine; but if the men did not load the coal, the machines could not travel. If the officials and workmen were loyal, and did their utmost to make machine-mining successful, he had no doubt that many of the difficulties would be overcome; but there were some that would tax the ingenuity of the colliery-managers and owners in the North Staffordshire district. Personally, he could not say that there was any direct reduction of cost; but as they overcame the difficulties, they were hoping that indirect gains would compensate them. Mr. Henshaw had stated that he did not think it desirable to use electric power in any mine where naked lights were used; but he did not agree with Mr. Henshaw on that point. No doubt there were dangers connected with electricity, and it would require careful handling in various ways. At present, however, he did not think that there was any reason for debarring electric power from going into a well ventilated mine, if suitable precautions were taken. He had seen coal-cutters worked by compressed air, but cutting by electricity was simpler than cutting by compressed air; and he considered that electric power was almost a *sine qua non* for successful and economical machine working of coal.

Mr. A. M. Henshaw said that electric coal-cutters emitted sparks; and he did not consider that an electric motor could work safely in the presence of gas. He would hesitate before applying an electric motor to cutting-machinery in a longwall face producing gas.

Mr. John Gregory asked Mr. Clarke to explain the advantages of the disc-machine over the bar-machine. He might mention that motors could be used that were absolutely sparkless.

Mr. J. T. Stobbs said that Mr. Clarke referred to the conservatism of colliery-officials in working their mines; this conservatism was not by any means confined to the class named, but might embrace inventors of coal-cutters, for no one machine could possibly be chosen to suit all colliery conditions. Considerations of dip and hardness of the coal-seam had an important bearing upon the subject, and upon the amount of slack produced. It was all very well to speak as if all the slack produced by a coal-cutter came out of the 5 inches of undercut, but in hard coals, after the "drop" occurred, the coal was in such an unshaken condition that it had to be broken, and a considerable amount of slack was produced, so that in some cases there was little, if any, increase in the percentage of round coal. An intelligent holer made a series of thin cuts, that allowed the weight of the roof to take effect, and they could cut with greater rapidity; this was an advantage that had no correlative in machine-cutting. He did not regard electricity as being an uncontrolled danger. When we remember the hundreds of installations at work daily in mines and the thousands of people who must come in contact with such plants—people, moreover, who were absolutely ignorant of the nature, properties, and peculiar dangers of electricity, and when we also remember the few accidents arising from its use, we must admit that there are many suitable applications in mining, and that it is so much under control that it is a remarkably safe form of energy, within the usual mining limits of voltage. He agreed with Mr. Gregory that the only way of avoiding the danger from sparking at the brushes of a motor was to adopt the polyphase system.

Mr. R. W. Clarke, with regard to the respective merits of the disc- and bar-machines, said that the only way to get the matter thoroughly discussed was to persuade an engineer interested in the bar-machine to read a paper on it. Mr. Mitcheson had referred to the cost of applying coal-cutting machines, but he (Mr. Clarke) had refrained from touching upon that question. The value of coal-cutting was more appreciated in thin seams than thick ones; and it was only in recent years that they began to be used in thick seams. The proportion of small coal was not so important an item in a seam 5 or 6 feet thick, as in a thinner one. In a seam 2 feet thick, the increased yield of round coal alone would justify the use of the mechanical coal-cutter. It was prob-

able that in North Staffordshire the methods of working might have to be modified so as to suit the machines, and this would conduce to greater success than if the methods were not altered.

Mr. B. Woodworth asked whether the Gartsherrie machine was still being successfully worked; and said that he had seen it over 25 years ago doing very good work with a comparatively low expenditure of power derived from compressed air.

Mr. G. A. Mitcheson said that he did not wish the members to consider that he took a gloomy view of the use of machines for coal-cutting; but he wanted to impress upon them that there were many difficulties connected with the use of machines that must be overcome. There were mines where the holing could not be made by hand-labour, and in such instances, whether they liked it or not, they must accept the exigencies of the case and adopt machinery, with either electric or compressed-air driving.

Mr. Clarke remarked that in 1891, the working-face was about 1½ miles from the pit-bottom, and the pressure of the compressed air was becoming very low, only about 19 or 20 pounds per square inch. The size of the pipes was increased, but they were obliged to introduce electricity, as the machines could not do the work when driven with compressed air so far away from the pit-bottom.

The President (Mr. W. N. Atkinson) moved a vote of thanks to Mr. Clarke for his valuable paper.

Mr. B. Woodworth seconded the resolution, which was cordially adopted.

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## DISCUSSION OF MR. J. T. STOBBS' PAPER ON "RECENT WORK IN THE CORRELATION OF THE MEASURES OF THE POTTERY COAL-FIELD."*

The President (Mr. W. N. Atkinson) said that Mr. Stobbs' paper developed a field of investigation, in which the members interested in geological formations must take a very great interest. He was not a palæontologist, but he appreciated that such a paper must be of interest to members who had devoted attention to this branch of science. The paper was of great practical value, because it indicated the means of locating the geological position of a coal-seam, after an examination of its accompanying fossils.

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 229.

Mr. J. T. Stobbs said that the question of the correlation of the seams was very early brought before him when he came to North Staffordshire, nearly four years ago. In visiting the different districts, students asked him which seam on the west side corresponded with the Cockshead on the east side; but he could not tell them. As a matter of fact there was great difficulty in correlating the beds of the North Staffordshire coal-field. In the past four years, four good horizons had been drawn through the district, and it was desirable that subdivisions should be similarly traced throughout the coal-field. He did not think that there was another coal-district which offered a greater field for investigation than this, and the mining students of North Staffordshire had an unique opportunity. There had been two first-class reputations made in the district: he had only to name Dr. Wheelton Hind, of Stoke, and Mr. John Ward, of Longton; and there was material enough in North Staffordshire for making many more.

He exhibited specimens of *Aviculopecten papyraceus* and *Glyphioceras* (?) *paucilobum* from the Seven-feet Banbury seam. In his paper he suggested that that horizon should be looked for on the eastern side of the coal-field, and he was glad to be able to report that since his paper was read he had found it at Sneyd colliery.

Samples from the B bed showed the manner in which *Spirorbis* occurred in bands above the Bowling Alley seam. The text-books stated that *Spirorbis*-bands were characteristic of the Upper Coal-measures; but these *Spirorbis*-bands showed that in future such bands should have no value attached to them in referring beds to the Upper Coal-measures as distinct from the Lower Coal-measures.

The samples from bed C shewed how *Lingulæ* were found in the shale below the Moss coal-seam. The members would also observe the *Lingula* in the sample of cannel. He mentioned in his paper that *Lingulæ* had only been found in the cannel at Silverdale, but the sample shewn was from Sneyd colliery. The fact that they were found over so large an area must be borne in mind when dealing with the origin of cannel-coal.

Specimens of shale from bed D, containing *Discina nitida* and *Lingula mytiloides*, were also exhibited.

# SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

## GENERAL MEETING,

HELD AT THE UNIVERSITY, BIRMINGHAM, FEBRUARY 10TH, 1902.

MR. T. J. DAVIES, VICE-PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

The following gentlemen, having been approved by the Council, were elected:—

MEMBER—

Mr. H. C. DICKSON.

STUDENTS—

Mr. CHRISTOPHER HATTON, Wyrley, Walsall.

Mr. WILLIAM BURNETT, Hednesford, Staffordshire.

The following supplemental paper was read by Mr. WILLIAM CHARLTON upon "A Method of Working the Thick Coal-seam in Two Sections."

In starting from a rib, some difficulty was generally experienced in getting the top coals, necessitating cutting and blowing; but, once a waste was formed, the coals would sink on the back-cog and break from those resting on the face-cog (Fig. 2) so that as soon as the back timber was withdrawn the top coals fell readily.

*Working the Bottom Section.*—The roads were driven in the Benches and Slipper coals, the dirt-parting over the Slipper coal affording good pricking. Cutting was made on one side and a shot fired in the fast corner at the bottom. No ripping was required to make height for tubs and horses.

The methods of getting the coals afterwards were identical with those pursued in working off the top section, the stalls being driven in the Benches and Slipper coals, the holing made in the parting between the Slipper and Sawyer coals, and the cogging was built under the latter seam.

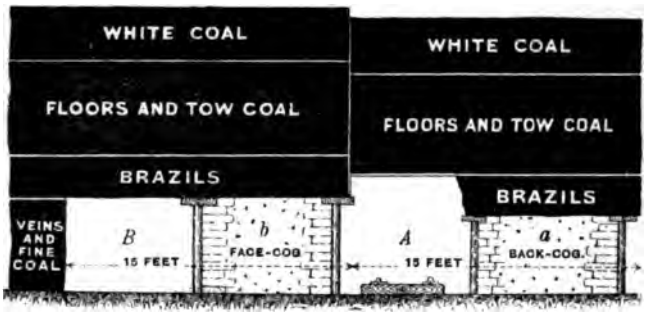


FIG. 2. CROSS-SECTION OF A SIDE OF WORK.
SCALE, 10 FEET TO 1 INCH.

*Remarks.*—In comparing the methods of working the Thick coal-seam in one section with those of working it in two sections, there are some obvious advantages in favour of the latter. In square work, probably little more than two-thirds of the seam is obtained, although the remaining third may be, and frequently is, partially recovered by working a second and even a third time in what is usually known as "rib-and-pillar work."

In working out this seam by either of the two methods described in this or the preceding paper, the produce per acre is much greater than when working in one section. It may be argued that the methods of working in two sections are more expensive,

as two sets of roads are required, one for the top and one for the bottom section, but when making the comparison the cost of gob-roading in the second working in rib-and-pillar pits must be taken into account.

But the three special features of the methods that justify attention are:—(1) The comparative freedom from gob-fires, (2) the manageability of the timbering, and (3) consequently the greater safety of the workmen employed. Fires, due to spontaneous ignition, are reduced in frequency because the coal and slack can be more completely removed. At no time, are trees more than about 10 feet long required, consequently, they may be relied on to support great weight, and can be set in sufficient abundance to allow of the miner working with considerable assurance of safety; indeed it is miners who have given most praise to the two methods of working.

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Mr. F. A. Grayston was somewhat surprised to hear that the method of working the Thick coal-seam, described by Mr. Charlton, resulted in fewer gob-fires, as his experience had been rather to the contrary. Owing to the top section having to be worked first, he found that air afterwards escaped through the gob, when the bottom section was in course of being worked, and thereby enhanced the danger of gob-fires; but the system of working in two sections became a necessity, under certain conditions of the Thick coal-seam, and it had the advantage of producing a larger yield of coal per acre.

Mr. W. H. Whitehouse said that he had known the Thick coal-seam to be worked, by a similar method, in the Kingswinford district, with considerable advantage; and they were able to deal successfully with the gob-fires. The late Mr. Brough, for many years H.M. inspector of mines in the South Staffordshire district, read a valuable paper on this subject in 1858, which contained many valuable suggestions, and was well worthy of being read by the members.

Mr. W. Charlton, replying to the discussion, remarked that the fires occurring in the bottom section were caused by the incomplete working of the top section. While claiming many advantages in working the Thick coal-seam in two sections, he was not prepared to go quite so far as Mr. Brough.

The CHAIRMAN (Mr. T. J. Davies), in proposing a vote of thanks to Mr. Charlton for his paper, remarked that he had had considerable experience in working the Thick coal-seam, and he had listened to the paper, which contained novel ideas, with much interest.

Mr. W. H. WHITEHOUSE seconded the proposition, which was carried unanimously.

# THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY COLLEGE, NOTTINGHAM, MARCH 8TH, 1902.

MR. G. ELMSLEY COKE, PRESIDENT, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen:—

MEMBERS—
Mr. HALDANE THOMAS CHRISTIE, Muzinto, Natal.
Capt. CHAMBERS DIDHAM, Hardwick Collieries, Heath, Chesterfield.
Mr. FRANK EVELYN SEELY, Calverton Hall, Nottingham.

ASSOCIATES—
Mr. JOHN GOODMAN, Creswell, Mansfield.
Mr. EDWIN HUSBAND, Creswell, Mansfield.

STUDENTS—
Mr. FRANCIS HENRY ELLIS, Sherwood Colliery, Mansfield.
Mr. LEONARD CLIFF HODGES, Babbington Collieries, Nottingham.

The SECRETARY read the balloting-list prepared by the Council for the election of officers for the year 1902-1903.

Mr. HENRY DAVIS (Derby) read the following paper by Sir Howard Grubb and himself on "A New Sight for Surveying-instruments":—

# THE GRUBB SIGHT FOR SURVEYING-INSTRUMENTS.

By Sir HOWARD GRUBB and HENRY DAVIS.

*Introduction.*—A paper on "A New Collimating-telescope Gun-sight for Large and Small Ordnance"* describes an invention which is destined to revolutionize the system of sighting ordnance, and will probably be extensively employed in surveying-instruments, whether for surface or underground use. The inventor of this new sight is Sir Howard Grubb, who has also read before that society another paper† describing the application of the sight to some surveying-instruments, reserving reference to underground surveying in order that the matter might be presented to a society more directly interested in the subject.

It is common to all sighting appliances, both for engines of war and for surveying, to demand of the human eye what is a physical impossibility, that is, to focus simultaneously two or more objects at different planes. Some eyes are more adaptable or more highly trained than others, and are able to overcome the difficulty to some extent, but it is evident that virtually to superpose the sight on the object will tend to make surveying more accurate, more rapid and less fatiguing. By the superposition of the virtual or "ghost" image on the object, a scale, cross or any other device is seen through the new sight projected on the object to be observed, and on practically the same plane. The errors due to parallax are eliminated.

*Description.*—The sight is preferably constructed of a short piece of rectangular brass tube about $\frac{3}{4}$ inch square, 3 inches long, open at both ends, and the object is viewed through the tube. About midway in this tube, fixed at an angle of 45 degrees, is a plate of glass, coated with a semi-transparent and highly reflective film.

* *Scientific Transactions of the Royal Dublin Society*, 1901, series 2, vol. vii., page 321.

† "Some New Forms of Geodetical Instruments," *Scientific Transactions of the Royal Dublin Society*, 1901, series 2, vol. vii., pages 385 to 390.

In order that the construction may be made quite clear, it is desirable to describe the original conception of the sight which is shewn in Fig. 1. At right angles to the square sight and opposite to the reflector a circular tube is fixed. At one end, *d*, is a diaphragm coated with some opaque material, through which are cut or photographed, cross-lines, a star, a scale or any other convenient device. At the base of this circular tube is an achromatic lens, *o*, of a focus suitable to the distance between the lens and diaphragm. This achromatic lens brings into parallelism the luminous rays from the markings on the diaphragm, which rays are bent at right angles to the reflector and directed into the eye of the observer, the result being that the rays from the diaphragm enter the eye under exactly the same conditions as if from the distant object, and he sees the image or sight-lines virtually superposed on the distant object, that is, at the same distance. The lines are shewn sharp and clear, without any strain to the eye, and there is no parallax: the cross-lines will coincide with the object at whatever portion of the sight-tube the eye is applied, this being due to the collimating lens, *o*, bringing into parallelism the rays exactly under the same conditions as they would if proceeding from cross-lines at a greater distance, instead of a small cross at a shorter distance. Sufficient brilliancy is obtained by the use of the semi-reflective film, chemically deposited on the surface of the inclined glass plate previously mentioned.

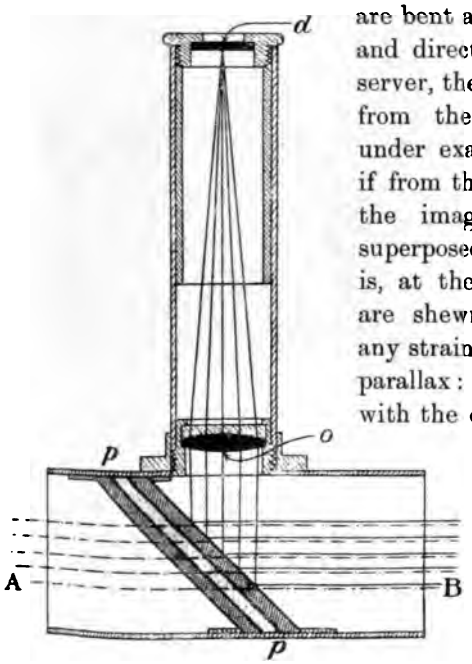

FIG. 1.

As a tube projecting at right angles to the sight would in all cases be more or less in the way when applied to surveying-instruments, a modification (shewn in Fig. 2), has been produced, in which the diaphragm is placed in a small hood or projection on the top of, or at one side of, the sighting-tube. The divergent rays

from the diaphragm are reflected from a silvered portion of a piece of the plane-glass which forms the back window of the sighting-tube, upon the concave surface of the front window, and are by it rendered parallel and again reflected into the eye of the observer in a manner exactly similar to the sight illustrated in Fig. 1.

In using the sight, the effect is very similar to looking at an object through faintly smoke-tinted glass, a brilliant image of the + or other device being superposed. The eye may take any position near the centre of the sight and at a greater or less distance from it, and there is the greatest ease and comfort in the operation of sighting the object. In order to demonstrate that the virtual image or sight is superposed on the object, a photographic picture has been taken, showing both the ghostly picture and the object equally well-defined (Fig. 3).

FIG. 2.

The same effect is produced in some other and well-known instruments by utilizing one-half of the pupil of the eye for forming one image on the retina and the other half of the pupil for forming the other image on the retina: but with such a device the eye must remain in a fixed position, and the process is difficult and wearisome.

It is not claimed for the new sight that it will displace the telescope in standard geodetical instruments such as the theodolite and level, but such instruments are often used for work for which they are not suitable, and in which their accuracy, delicacy, weight and size are a disadvantage.

*Subtense Instruments.*—Reference has been made to the possibility of a scale being affixed to the diaphragm in place of a cross or other device, such a scale being necessary in subtense instruments by which measurements may be made from a point or

station by projecting the scale upon a staff of known length, as illustrated in Fig. 4. The staff has two marks placed upon it, usually 6 feet apart, and simultaneously to the bearing of the staff being read, the interval between those two marks on the staff is measured by the number of divisions, which that space occupies on the sight-scale, the number of divisions occupied being of course greater as the distance of the staff is less and *vice-versa*.

In measuring boundary-lines which are visible from any one point, the assistant has only to hold the staff upright at the various stations, and the distance may be measured in the time which it takes the staff-carrier to walk round from station to station.

FIG. 3.

*The Circumferenter.*--Miner's dials or circumferenters have been from time to time greatly improved, verniers have been constructed to read to single minutes, a degree of accuracy which is difficult to plot, centres have been lengthened to effect accuracy in reversing, fine adjustment-screws have been added, in some cases a telescope has been attached which, except in main roads, is out of place in a pit and always difficult to illuminate satisfactorily. The sights, however, are the same, without improvement since the earliest miner's dial was designed; consequently the same

physical difficulties occur, that is, the attempt to focus the fore-sight, back-sight and the object simultaneously, the difficulty of keeping the eye rigidly fixed at the centre of the back-sight to avoid errors in parallax, and the absence of light at that sight.

FIG. 4.

The application of the new sight to instruments for underground surveying will appeal to the mining-engineer, as with a lamp, a brilliantly illuminated cross or other device may be cast upon the staff or other object used in the pit for measuring the vertical or horizontal angle. Fig. 5 shews clearly the effect of the invention, and indicates the ease of surveying with the Grubb sight.

FIG. 5.

In the construction of the miner's dial, the necessary distance between the fore- and back-sights are entirely obviated, the collimating sight only requiring 3 inches in length, so that the greatest space required is regulated by the diameter of the compass-box, usually 5 or 6 inches. Fig. 6 and 7 illustrate the miner's dial with the sight attached and, with this construction, angles can be measured up or down to fully 90 degrees, and may read to 3 minutes of arc; and in both instruments, the sight is hinged

so that back-sights and fore-sights may be taken by simply reversing that portion.

Fig. 6 is constructed with the usual circular compass, horizontal-vernier reading to 3 minutes, and the Grubb sight mounted on an arc reading to 90 degrees both ways, with a vernier reading to 3 minutes. Fine adjusting screws are fitted for reading both horizontal and vertical angles.

Fig. 6.

Fig. 7 differs from Fig. 6 inasmuch as a trough-compass displaces the circular compass-box, and this is fixed under the horizontal plates, the ends projecting beyond the circumference, and an additional fine adjustment is supplied, so that the needle may be read with ease and brought to zero accurately. The circular compass-box being displaced, there is ample room for two large and sensitive levels which are fixed at right angles.

The advantages accompanying the use of the Grubb sight in mine-surveying may be summarized as follows:—(1) The minimum of weight and diameter; (2) the ease by which the sight may be illuminated; (3) the avoidance of errors due to parallax; (4) the rapidity and ease of reading the direction of the bearing and the angle; and (5) angles of any inclination or declina-

FIG. 7.

tion may be taken with an instrument, constructed with a semicircle over the compass-box, with a sight which is both compact and extremely light.

*Portable Surveying-instruments.*—Portable instruments for rough surveying, such as the clinometer, Abney level, prismatic compass, etc., may be constructed with the Grubb sight, and without complicating the effect of observation, the level, angle of

declination or direction may be simultaneously observed, and a full description of such instruments may be read in the second paper previously mentioned.

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Mr. R. F. PERCY (Nottingham) thought that he might assure Mr. Davis, presuming that a slight accident would not displace the adjustment of the mirrors, that there was a great future before the new instrument.

Mr. J. A. LONGDEN (Stanton-by-Dale) moved a cordial vote of thanks to Sir Howard Grubb and Mr. H. Davis for their paper, remarking that he had known cases where it was very difficult from lack of space to work the sights, and impossible to get their heads into the limited area. With the improved instrument they would be able to stand at a distance, and take their sights. He was sure all surveyors were greatly indebted to the authors of the paper.

Mr. G. ALFRED LEWIS (Derby) said that, in spite of the very able way in which the authors had presented the subject to the members, he was afraid that it was incomprehensible until they had a chance of looking through the sight. He had had considerable experience in rifle-shooting, and the focussing of the back-sight, of the fore-sight, and of the target, at different distances, was a very difficult task. It was practically a physical impossibility to co-ordinate them precisely, and the only way was at the best, but approximately correct. Members, who had been engaged in surveying, either recently or many years ago, would know the difficulty of (1) illuminating the fore-sight, and (2) the awkwardness of focussing the three distances simultaneously. He had had, through the courtesy of Mr. Davis, the opportunity of looking through the new sight, and it was extremely easy to illuminate by holding the candle, not in front but at the side of the centre. Under the present arrangements, it was difficult to get the sight exactly into a line with what they were sighting at the far end, and if they moved the eye a small distance on one side or the other the sights were off the candle immediately; but with the new instrument if they once put the cross upon an object, it was possible to move the eye, and not thereby remove the apparent position of the cross from the object. With regard to the trough-compass, he thought that it would only be possible to use it for fast-needle surveying. There was another point: when surveying, it was

necessary first of all to look through one end of the instrument, and then, without moving it round, to look through the other end. It seemed to him that with this instrument they could look through only one end, and to make it equally applicable to those appliances now in use, some modification was required, or there must be two sights, one placed above the other.

Mr. I. H. Saxton (Grassmoor Colliery) said that he had taken the opportunity of looking through this sight, and it could certainly be illuminated very easily, but it struck him that the cross was rather large. He had not had a chance of seeing an object at a great distance, but it seemed to him that the cross would almost obscure the light of a lamp at a distance exceeding 200 feet.

Mr. H. Davis, in replying to the discussion, said that, inasmuch as the sight was protected by the other parts of the instrument, it was less likely to be put out of adjustment than a dial provided with a telescope or ordinary sights. The arrangement was so solidly constructed that there was practically no liability to derangement, while it was protected against dust by a piece of glass at each end. Referring to the application of the Grubb sight to the rifle, one of the popular papers described the sight as rendering it easier to hit an object than to miss it. The illumination of the sight was accomplished by holding a miner's lamp at a little distance, it being quite unnecessary to apply it closely. In fact if they were sighting on to a lamp in the pit a small reflector would throw on the lamp a most brilliant cross. Mr. Lewis raised the question of taking a fore-sight and back-sight without disturbing the instrument. Of course, dials with verniers were provided with plates which revolved, leaving the row of figures fixed while the vernier revolved. But as there was a consensus of opinion that it was better to revolve the sight independently of the plates there was no difficulty, and the Grubb dial will be so constructed in future instruments. The special dial with the trough-compass, was only useful when they were making a fast-needle survey; and if they were making a loose-needle survey, the circular compass-dial must be used. But the advantages were so great in using a trough-compass in having a long needle, which was never obstructed by other portions of the instrument, that there would probably be few dials eventually used with a circular compass. It was true that in the sights exhibited the cross seemed rather coarse, and might cover too much of the

area of the sight; but the sights on the two surveying-instruments exhibited had been made rather hurriedly, and the crosses were rather coarse. At the same time, it should be remembered that the cross did not get coarser with the enhanced distance of the object, and the same cross remained the same whatever the distance of the object to which they were sighting. The cross, or a scale, could be photographed on to the glass as finely as could be desired, and, of course, they could use any design that they thought convenient. The main feature of this new sight was that errors due to parallax were obviated—and they could not be obviated in the sights at present in use. Moreover, the ease and rapidity with which the new sight enabled the work to be done, outdistanced the ordinary sight, and could not fail to be appreciated.

The further discussion of the paper was adjourned.

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## DISCUSSION OF PROF. H. STROUD'S PAPER ON "MAGNETIC DECLINATION AND ITS VARIATIONS,"* AND MR. H. D. HOSKOLD'S "REMARKS."†

Mr. R. F. Percy (Nottingham) said that in a discussion on this subject a few years ago one gentleman expressed his desire to see the use of the compass-needle for mine-surveying entirely prohibited,‡ but this appeared to be an extreme position to assume, and one for which there was little justification. He believed, if the facts so well summarized by Prof. Stroud were intelligently appreciated and proper care taken, that the mining-dial might still be relied on and very accurate plans drawn. During the discussion of the paper Prof. Stroud formulated a rule, which should invariably be observed in important surveys based on the magnetic meridian. Prof. Stroud said that, "in making an underground survey, no definite conclusion could be drawn as to the magnetic meridian, unless the needle remained parallel to itself, as tested at several positions along a base-line. If the direction of the magnetic needle be indicated on the plan at the various positions of the survey, and it be found that the needle remained parallel to itself at several positions, as tested along a base-line, then it might be concluded that there was no magnetic disturbing cause in the

* *Trans. Inst. M.E.*, 1894, vol. vii., page 268.

† *Ibid.*, 1901, vol. xxi., page 18. ‡ *Ibid.*, 1895, vol. ix., page 426.

immediate neighbourhood."* It had been his (Mr. Percy's) practice to observe this rule, and he had often been impressed by the fact that mistakes would have followed neglect of the precaution, and encouraged by the excellent results obtained when this test of parallelism had been applied.

A survey made last year confirmed the value of the test in a very decided way, and some of the inconsistent readings of the needle might prove of interest. The nucleus of the work consisted of four main roads, in the form of a square and having a circuit of nearly 3 miles. Fortunately, a shaft was situated on each of two adjacent sides of the square: these shafts were 21 chains apart underground, and 14 chains apart at the surface. The line joining the centres of the shafts was the ultimate reference-line of the survey, but the magnetic needle was used as a base-line underground, as a matter of convenience. Several experiments were made in applying the "Stroud" test, but although the opportunities were apparently all that could be desired, only 3 sets of tests were satisfactory. At each of these testing-places, the needle gave identical bearings at both ends of the test-line, and as was afterwards proved the 3 sets were also in mutual agreement. On the other hand, for no apparent reason, several localities gave extraordinarily conflicting results:—I. The meridian varied 1° 15′ at the ends of the test-line. II. Three tests: at No. 1 station the needle read 122° 15′; at No. 2 station, 119° 45′; at No. 3 station, 120° 6′; while the true bearing was 120° 0′. III. Three tests: at No. 1 station the needle varied 0° 10′ from the reading at No. 2 station, and 2° 45′ from that at No. 3 station. In all these cases there could have been no error in manipulation, as the tests were repeated and the readings were the same. There was no reason to suspect the presence of iron, and search and inquiries failed to find an explanation of these remarkable local magnetic irregularities. The three successful sets of tests gave meridians which were harmonious, and which also agreed with that determined on the surface. The line through the shafts, proved by a triple parallel test, was 88° 38′, while the calculated resultant bearing underground was 88° 35′. He (Mr. Percy) thought that these facts warranted the conclusion that the dial was a trustworthy instrument, when it was properly used.

* *Trans. Inst. M.E.*, vol. ix., page 29.

Mr. G. SPENCER (West Hallam) did not consider that the magnetic needle was always reliable for making surveys, owing to possible local attraction and other disturbances. Some nine or ten years ago, while making a survey of a mining estate, in taking the bearing of a line on the surface, he was astonished to find that the needle continued to vary to such an extent that he had to give up the attempt for a time, thinking that the fault lay with the dial. A day or two afterwards he read that on the corresponding date there had been a great magnetic storm, and the variations recorded amounted (he believed) to about 2 degrees.

Mr. I. H. SAXTON (Grassmoor Colliery) said that Prof. Stroud gave a table showing that the daily declination of the needle amounted to 10 minutes, a variation that explained what to him had been incomprehensible in surveying. He had taken a magnetic base-line when starting, and on finishing 2 or 3 hours later had tried to take a check-reading; but, no matter how carefully the work had been done, he had often found a difference in the reading of between 6 and 12 minutes. Prof. Stroud showed that the difference in the hourly means of declination—between the hours of 8 a.m. and 1 p.m. in winter was 6·9 minutes and between 8 a.m. and 1 p.m. in summer was 12·2 minutes, which was quite enough to explain any apparent inaccuracy in the check-reading of the needle. Prof. Stroud referred to a magnetic storm in February, 1892, in which in two or three hours, the difference of the set of the needle was 1° 40′. In underground surveying, it was sometimes necessary to re-survey main roads which were already marked on the plan; and in future, in the case of any difference, he should be inclined to attribute it to a magnetic storm, and not to inaccurate surveying. This declination of so many minutes in a day was an important matter, as an error of only 3 minutes in a survey-length of 40 chains would amount to 3½ links, and an error of 6 minutes in a survey-length of 1 mile would amount to 14 links. The only way to avoid this variation would be to take a test in the meridian base-line on the surface, as nearly as possible at the same time as they took the meridian base-line in the pit.

The PRESIDENT (Mr. G. E. Coke) observed that in his experience of surveying important work needed to be gone over several times. The ordinary miner's dial, if properly used, gave very good results;

but he allowed that there was an opening for a more accurate instrument.

Prof. H. Stroud (Durham College of Science) wrote that Mr. R. F. Percy's interesting results give examples of cases where the compass-method of surveying was satisfactory, as well as cases where it was inapplicable. It would be of additional interest to know whether the positions, at which Mr. Percy found the method unsuitable owing to local but unknown magnetic disturbances, were in any way connected with the ridge-lines referred to by Principal Rücker,* who gives the relations of the lines of disturbance to the principal coal-fields of the United Kingdom.† He approved of Mr. Percy's conclusion that the dial was a satisfactory instrument when it was properly used.

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## DISCUSSION OF MR. A. L. STEAVENSON'S PAPER ON "THE MODE OF OBTAINING A TRUE NORTH LINE,"‡ AND MR. H. D. HOSKOLD'S "REMARKS."§

Mr. R. F. Percy (Nottingham) remarked that he agreed with Mr. Hoskold that the true north line was of no real use, and should only be regarded as an artistic finish to a plan. He differed from Mr. Steavenson that "it is absolutely necessary that in practice, a true north line should be drawn on the mine-plan, and another on the surface, to enable the correctness and variation of the needle to be tested."‖ His opinion was that, while it looked well on the plan, it was not advisable to stake out the line on the surface. If such a line were to be staked out, meridian observations might be confined to that line, and it might happen that bearings would be taken at a place where the needle would not give normal bearings, and the result might be disastrous. On account of probable shrinkage, and possible torsion, of a plan, it was essential that such observations should be made in the district beneath which the coal was being worked; and where coal was worked away to the west, a point due north of the shafts was certainly not the proper place to take a meridian. Bearings to fix a meridian ought to be taken where the lines of sight were convenient, and the "Stroud" test should be applied.

* "The Magnetic Survey of Great Britain," *Trans. Inst. M.E.*, 1895, vol. ix., page 417.

† *Ibid.*, vol. ix., page 418.

‡ *Ibid.*, 1895, vol. x., page 53.

§ *Ibid.*, 1901, vol. xxi., page 28.

‖ *Ibid.*, vol. xxi., page 33.

The true north line could be drawn with great accuracy by the aid of the Ordnance Survey maps, if a simple formula be applied. These sheets are drawn with parallel sides and square corners, and therefore on any given map, the sides cannot both be truly north. There is only one cut-line running between the Derbyshire and Nottinghamshire maps which runs exactly north and south. The Derbyshire and Nottinghamshire maps are all plotted to the meridian which passes through Dunnose in the Isle of Wight, and the survey is spread out on each side of that line in accordance with flat-earth ideas. The cut-line, dividing maps on the 6 inches to the mile and other scales, and passing through Wollaton, Newstead and Mansfield in Nottinghamshire, Whitwell in Derbyshire, and thence into Yorkshire, is a true north line. All the side-lines of the Nottinghamshire maps on the east diverge to the right; and all the side-lines of the Derbyshire maps diverge to the left. The extent of this divergence can easily be computed: while the widths which separate minutes of latitude are practically everywhere alike in the coal-field, the widths between the lines of longitude diminish when travelling northwards; and 1 minute of latitude is everywhere in the district about 6,085 feet (92·20 chains), but 1 minute of longitude in Nottingham is 3,675 feet (55·69 chains) and at Chesterfield it is only 3,651 feet (55·32 chains). The lines of latitude are marked on the 6 inches to the mile maps, and if the cosine of the angle be multiplied by 6,100 feet (92·43 chains) the product is the width of 1 minute of longitude. From these figures it is a simple matter to calculate how much the true north line departs from the side lines of any map on the scale of $\frac{1}{2,500}$ or 25·344 inches to the mile. After ascertaining approximately how far the particular point on the map is from the Dunnose meridian, one should multiply this distance by the secant of the latitude running north of the point, and multiply again by the cosine of the latitude (less 1 minute) which crosses south of the spot, and the product will be a number slightly in excess of the original distance. The excess is the measure of the departure of the cut-line from the true north in a range of 1 minute of latitude.

As an example, suppose it is desired to draw a north line on a $\frac{1}{2,500}$ map through Chesterfield church. The quarter-sheet of the 6 inches-to-the-mile maps shews the church 29 chains from the edge, and an index map will shew that it is 9 miles more to the Dunnose

line, the total distance being 749 chains. The latitude-lines above and below the church are 53° 15′ and 53° 14′. And 749 chains by secant 53° 15′ by cosecant 53° 14′ equals 749·292 chains. Thus the cut-line diverges about 29 links in 1 minute of latitude; and 29 links in 9,220 links is equivalent to 1 in 316 or 11 minutes. This shows tnat, at a point 749 chains from the Dunnose meridian, the true north line differs 11 minutes or 25⅓ links per mile from the edge-line of the $\frac{1}{2,500}$ map. A line can now be drawn on the $\frac{1}{2,500}$ map in the neighbourhood of the church, so inclined that the northern end is 25 links nearer to the top right-hand corner than the southern end is distant from the bottom right-hand corner. Such a line will be as nearly true north as it is possible for a line to be drawn, and if desired it may be transferred to a larger-scale plan. Combining the factors, we obtain the following formula specially applicable to the $\frac{1}{2,500}$ maps of Derbyshire and Nottinghamshire:—$86{\cdot}768\ [C \sec\theta \cos(\theta - 1') - C] = L$. In which C is the distance of the place from the Dunnose line in chains; $\theta$, tne angle of the line of latitude passing north of the place; and L, the divergence of the true north line from the edges of the map in links per mile.

In conclusion, he (Mr. Percy) thought that by this method the true north line may be laid down with all the accuracy that can reasonably be required on a colliery-plan, since the total error need not exceed an arc of 1 minute.

Mr. G. Spencer (West Hallam) said that he had found the following method of ascertaining the true meridian to answer very well. On the margins of the 6 inches Ordnance Survey maps the true longitudes and latitudes are marked, and if any convenient longitude be taken and a line be drawn joining the northern and southern edges of the sheet, such a line will generally pass through a number of fences or near easily recognizable objects. Then scale from the line to the intersection of the fences all along the route—the greater the number the better. In the case of a new survey, the distances so obtained should be pegged out on the surface, and a trial-line ranged through any desired length, say from the pegs at the two extremes. Off-sets must now be taken from the trial-line to the pegs, and the mean line deduced therefrom will be a true north-and-south line, which may be used as a base-line. If it be desired to lay down a true north-and-south line on an existing plan,

it will only be necessary to transfer the distances of any objects scaled from the meridian line drawn on the Ordnance Survey sheets to the plan, and to calculate the mean line in the same manner as in the former case. The mean line thus ascertained will be a true north-and-south line, provided the plan be accurate. A few years ago, he (Mr. G. Spencer) adopted the former method and ranged a true north-and-south line, over 3 miles in length, through an estate; and he sent a tracing from the $\frac{1}{2,500}$ Ordnance Survey map shewing the line and fences for a distance of a few chains on each side, to the Ordnance Survey Office, Southampton, for verification. The Director-general of the Ordnance Survey very courteously had the true meridian marked on the tracing, and the angular difference between the two lines did not amount to 1 minute of arc, a degree of accuracy which could not be exceeded by astronomical observations with an ordinary surveyor's transit-theodolite.

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## DISCUSSION OF MESSRS. G. AND G. C. FOWLER'S PAPER ON "SYSTEMATIC TIMBERING AT THE BABBINGTON COLLIERIES."*

Mr. J. A. Longden said that he had had an opportunity of going down this pit and seeing the steel-props in use; and certainly, it was one of the prettiest sights that he had ever seen in a pit. It seemed to him that the question of steel *versus* tapered wooden props was an important question. He might say that he had taken out the figures at their own pits for three years; and the economy that he mentioned at Nuneaton with tapered props had been confirmed. The tapering of the props had undoubtedly reduced the consumption of timber by more than 20 per cent. At a depth of 3,000 feet, he (Mr. Longden) reckoned that the weight per square foot of area to be supported would be about 200 tons; and as one prop, 6 inches in diameter, would only sustain 40 tons, it seemed to him that the wood would require to be closely set at a depth of 3,000 feet. He thought that the difficulty in the future would be the squeezing of the coals, and as the President (Mr. G. E. Coke) was interested in the work of the Coal Commission he might bear in mind that question, when estimating the available coal yet ungot. Messrs. Fowler's paper

* *Trans. Inst. M.E.*, 1901, vol xxi., page 124; and vol. xxii., page 256.

resolved itself into this—they must either hold up the roof or let it down. The question was: Which were they going to do? If they went in for half-measures they broke the roof or they broke the timber. Messrs. Fowler went to one extreme, and he thought that Mr. Hepplewhite went to the other. He (Mr. Longden) could not tell the members which was the best method, because he did not know the conditions of their mines; but he could tell the members that he was using tapered props successfully.

The PRESIDENT (Mr. G. E. Coke) thought that the most valuable point of Messrs. Fowler's system had been missed, namely, keeping up the clod which lay between the Coombe coal and the Top Hard coal-seam. He had no doubt that it had been found more economical than shifting all the muck. With a clod roof he thought that Messrs. Fowler's system of keeping it up by bars was well worth trying.

Mr. G. SPENCER remarked that two years ago he had tried tapered, tubular steel props, so that they might enter the floor instead of breaking the roof. He found that they answered very well, and that he obtained the same result as by the use of the Hepplewhite tapered props; but the plan was applicable only where the floor was harder than the roof.

The discussion was then closed.

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## DISCUSSION OF MR. M. H. HABERSHON'S PAPER ON "A JOINT COLLIERY RESCUE-STATION."*

Mr. JNO. PIGGFORD (Teversal) said that his company were prepared some time ago to join neighbouring collieries in forming a central rescue-station for their own district. And for the purpose of becoming thoroughly acquainted with the details of the arrangements recommended, Mr. J. A. Longden went with him to Normanton, to inspect the apparatus and appliances provided by Mr. W. E. Garforth at Messrs. Pope and Pearson, Limited's collieries. After noting, however, the extremely exhausted state in which the men who were experimenting returned from the testing-gallery after only a few minutes

* *Trans. Inst. M.E.*, 1901, vol. xxi., page 100; and vol. xxii., page 195.

exposure to the gas and smoke-fumes with which the galleries were charged, they came to the conclusion that the experiments were not only dangerous to health, but were also, with the present imperfect appliances, not likely to serve any useful purpose as means of rescue, and they had therefore abandoned the idea until more perfect appliances should be obtainable.

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The members visited the Gedling colliery of the Digby Colliery Company, Limited.

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## GEDLING COLLIERY.

Gedling colliery, now being sunk, is situated four miles east of Nottingham. It is the most easterly attempt to work the extension of the Midland coal-field, concealed beneath the Permian and Mesozoic formations.

A bore-hole, which reached the Top Hard coal-seam, a little under 1,500 feet in depth, commenced in the Keuper marls. It then passed through the full thickness of the Bunter sandstone, a little Magnesian Limestone, Permian slates, and a considerable thickness of remarkable red, purple and yellow mottled shales, before reaching the usual Coal-measures of the district. These mottled shales are considered to be representative of the Upper Coal-measures of North Staffordshire.

Two shafts are being sunk, 16 feet and 18 feet respectively in diameter, and each will be lined with 180 feet of coffering followed by 280 feet of tubbing, which will take them to the impervious Permian slates. The 16 feet shaft is about 450 feet deep, and the final tubbing-curb will shortly be inserted; and the 18 feet shaft is 370 feet deep, and the third length of tubbing, 63 feet long, is being closed. The 16 feet shaft is now yielding 800,000 gallons and the 18 feet shaft a little over 2,000,000 gallons of water per day.

In the 16 feet shaft, there are three Evans differential ram pumps, and one Evans piston pump; and in the 18 feet shaft, there are three Evans piston pumps. All the pumps throw directly to the surface and in one lift; they are suspended by iron chains from girders at the surface, and they are raised and lowered by duplicate steam capstans (5 tons) and four sheave rope-blocks.

There are eight Lancashire boilers, 30 feet long and 8 feet in diameter, working at a pressure of 150 pounds per square inch, two are fitted with Proctor shovel-stokers, and the remainder with Caddy bars for hand-firing.

The winding-engine at the 16 feet shaft has 2 cylinders, 25 inches in diameter by 4 feet stroke, and is fitted with Eatock balanced slide-valves, and a drum, 10 feet in diameter; and the winding-engine at the 18 feet shaft has 2 cylinders, 24 inches in diameter by 5 feet stroke, and is fitted with plain slide-valves, and a drum, 8 feet in diameter.

At each shaft, there is a scaffold capstan, capable of lifting 10 tons from each of two drums.

# THE MINING INSTITUTE OF SCOTLAND.

## TWENTY-FIFTH ANNUAL GENERAL MEETING,

HELD IN THE HALL OF THE INSTITUTE, HAMILTON, APRIL 10TH, 1902.

MR. JAMES S. DIXON, RETIRING PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The SECRETARY read the report of the Council as follows:—

## COUNCIL'S REPORT.

The Council have pleasure in submitting their twenty-fourth annual report, embracing the proceedings of the Institute for the year ending at this date.

The number of members on the roll at this date is as follows:—

| | |
|---|---|
| Honorary Members ... ... ... | 3 |
| Life Members ... ... ... | 8 |
| Life Associate Member ... ... ... | 1 |
| Members (subscription £2 2s.) ... | 148 |
| Members (subscription £1 5s.) ... | 223 |
| Associate Members ... ... ... | 21 |
| Associates ... ... ... ... | 11 |
| Students ... .. ... ... | 14 |
| Non-federated Life Member .. | 1 |
| Non-federated Members (subscription £1 1s.) | 19 |
| Non-federated Members (subscription 10s. 6d.) | 12 |
| Total ... | 461 |

These figures compare with those of last year as follows:—

| | | |
|---|---|---|
| On the roll at April, 1901 ... ... | | 449 |
| Added during the year ... ... ... | | 40 |
| Total ... | | 489 |
| Died ... ... ... ... | 4 | |
| Retired ... ... ... ... | 9 | |
| Cut-off through non-payment of subscriptions ... ... ... | 15 | 28 |
| At present on the roll ... | | 461 |

There has been a net increase for the year of twelve, a gratifying improvement in the membership; and a further increase is not only desirable, but quite practicable, if members will bring the advantages of the Institute under the notice of those who are not already members.

The papers which have been read and published during the year are:—

"Unwatering and Developing of a Lanarkshire Colliery." By Mr. Robert Broom.

"What is the Least Possible Waste in Working Coal." By Mr. James Barrowman.

"The South Lesmahagow Coal-field." By Mr. John M. Cairncross.

"Rand Conglomerates, Transvaal." By Mr. Hugh Pearson.

"Practical Results of Changing the Motive Power of an Underground Pump from Steam to Electricity." By Mr. Hugh P. Swann.

The discussions have been somewhat meagre; and it is very desirable that a larger proportion of the members should shew their interest in the papers, by taking part in the discussions either in person at the meetings, or by letter addressed to the Secretary.

No doubt the irregular and tardy issue of the *Transactions* for the last year or two has prevented a timely and full perusal of the papers in preparation for discussion; but the Council are taking steps to bring about a more regular system of issue.

The International Engineering Congress, which met in Glasgow in September, with the mining section of which this Institute was associated, gave the members an opportunity of attending the meetings of the Congress in the eleven different branches of engineering there represented: and the excursions organized in connection with the Congress were also open to the members. The excursions of the mining section (which embraced the annual excursion of this Institute) were to the oil-works of the Broxburn Oil Company, at Broxburn, and to the Priory, Whistleberry and Hamilton Palace Collieries in the Hamilton district; they were attended by a large proportion of the members. A description of these works appears in the *Transactions*.*

As usual your delegate attended the Conference of Delegates of Corresponding Societies of the British Association, the meetings being held in Glasgow in October. Considerable discussion took place as to the best means of utilizing these annual conferences, so

* *Trans. Inst. M.E.*, 1901, vol. xxii., pages 573 to 584.

as to further the ends of science through the Association. The societies represented at the conference are so varied that it is difficult to choose subjects for discussion which are of general interest to the whole body of delegates; at the same time, an opportunity is offered to any delegate of putting forward proposals concerning the special branch of science in which his society may be interested. Those subjects which lie within the scope of this Institute are the registration by photography of sections of strata, records of borings and of underground temperatures, phenomena of glaciation, recording of erratic blocks, and coast- and river-erosion, on all of which subjects there are Committees of the British Association desirous of receiving and preserving records. Members, who have an opportunity of taking photographs of typical or interesting strata, or of collecting information on any of the subjects mentioned, are invited to communicate with the Secretary. A list of the papers on subjects of interest to the members of this Institute has been printed in the *Transactions*.*

The societies and technical periodicals with which an exchange of *Transactions* is made now number 64. A list of them is printed on the card which is issued yearly to the members. The volumes thus received form a very valuable portion of the library.

The donations to the library during the year, in addition to those by exchange, are as follows:—

| Donors. | Donations. |
|---|---|
| Mr. Henry Aitken ... | ... Folio Working Drawings of Coal-Mining Plant, by Mr. T. Povey Harper. |
| | The Mineralogy of Scotland, by Dr. M. Foster Heddle. 2 Vols. |
| Mr. H. M. Cadell ... | ... Paper on the Geology of the Oilshale-fields of the Lothians. |
| Mr. Jas. S. Dixon ... | ... £2 12s. 6d. for the purchase of Books. |
| Mr. J. T. Robson ... | ... 1. Report of H.M. Inspector of Mines for the South Wales District, 1900. 2. District Statistics 1900. 3. Report on Explosion at Universal Colliery. 4. Report of Explosion at Blaendare Slope Colliery, Pontypool. |
| Mr. J. M. Ronaldson ... | ... List of Mines, 1900. |
| | General Report and Statistics parts I., II., III., IV., Report of Inspector of Mines for West Scotland 1900. |
| Mr. James T. Forgie ... | ... Set of Transactions of Glasgow Geological Society, 25 vols. value £5 15s. |

* *Trans. Inst. M.E.*, vol. xxiii., page 71.

| Donors. | Donations. |
|---|---|
| Mr. B. T. A. Bell ... ... | Canadian Mining Manual |
| Mr. Bennett H. Brough ... | Paper on the Scarcity of Coal. |
| Messrs. Longmans Green & Coy. | Volume on Mine-surveying by Arnold H. Lupton. |
| Mr. T. Lindsay Galloway ... | Paper on the Campbeltown Colliery and Light Railway. |
| Mr. W. E. Teale ... ... | A Meyer safety-lamp. |

Considerable additions have also been made to the library by purchases.

The Council regret to report the death of one of their number during the year, namely, Mr. Michael Ross, who was one of the originators of the Institute in 1878 and who had been a member of Council almost continuously since then. The Council has recorded on its minutes the sense of the loss which the Institute has sustained by the death of Mr. Ross.

The Treasurer's accounts shew that the financial condition of the Institute is satisfactory.

There have been seven meetings of Council during the year.

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The report was unanimously adopted.

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The SECRETARY read the following abstract of the Treasurer's accounts for the year, which was adopted: —

## The Treasurer in Account with The Mining Institute of Scotland
### For the Session 1901-1902.

| Receipts. | | | £ | s. | d. |
|---|---|---|---|---|---|
| To Balance brought forward ... ... ... ... ... | | | 299 | 16 | 9 |
| „ Subscriptions— | | | | | |
| 11 Members, | Session 1900-1901 | at 42s. 0d. | 23 | 2 | 0 |
| 1 Member, | Session 1899-1900 | „ 15s. 7d. | 0 | 15 | 7 |
| 3 Members. | Session 1900-1901 | „ 25s. 0d. | 3 | 15 | 0 |
| 2 Associate Members | „ | „ 42s. 0d. | 4 | 4 | 0 |
| 1 Student | „ „ | „ 25s. 0d. | 1 | 5 | 0 |
| 131 Members, | Session 1901-1902 | „ 42s. 0d. | 281 | 8 | 0 |
| 1 Member, | „ „ | „ 22s. 5d. | 1 | 2 | 5 |
| 1 „ | „ „ | „ 12s. 6d. | 0 | 12 | 6 |
| 202 Members | „ „ | „ 25s. 0d. | 252 | 10 | 0 |
| 23 Associate Members | „ | „ 42s. 0d. | 48 | 6 | 0 |
| 7 Associates, | „ „ | „ 25s. 0d. | 8 | 15 | 0 |
| 15 Students | „ „ | „ 25s. 0d. | 18 | 15 | 0 |
| 18 Non-federated Members | „ | „ 21s. 0d. | 18 | 18 | 0 |
| 11 „ | „ „ | „ 10s. 6d. | 5 | 15 | 6 |
| 2 Members, | Session, 1902-1903 | „ 42s. 0d. | 4 | 4 | 0 |
| 1 Member, | „ „ | „ 21s. 0d. | 1 | 1 | 0 |
| 1 „ | „ „ | „ 29s. 6d. | 1 | 9 | 6 |
| 2 Members, | „ „ | „ 25s. 0d. | 2 | 10 | 0 |
| „ Donation to Library ... ... ... ... ... | | | 2 | 12 | 6 |
| „ *Transactions*, &c., sold ... ... ... ... ... | | | 12 | 16 | 2 |
| „ Rents of Hall ... ... ... ... ... | | | 5 | 6 | 0 |
| „ Interest on Deposit Receipts ... ... ... ... | | | 7 | 4 | 11 |
| | | | £1.006 | 4 | 10 |

| Payments. | £ | s. | d. | £ | s. | d. |
|---|---|---|---|---|---|---|
| By The Institution of Mining Engineers ... | | | | 425 | 19 | 10 |
| „ Printing and Stationery ... ... ... | | | | 35 | 6 | 10 |
| „ Books and Bookbinding ... ... ... | | | | 19 | 7 | 6 |
| „ Furnishings for Hall ... ... ... | | | | 7 | 14 | 0 |
| „ Rents of Hall ... ... .. ... | | | | 27 | 13 | 0 |
| „ Gas and Assessments ... ... ... | | | | 5 | 10 | 4½ |
| „ Stamps, Carriages, Telegrams, etc. ... | | | | 13 | 6 | 9 |
| „ Sundry Payments ... ... ... ... | | | | 3 | 2 | 3 |
| „ Cleaning Hall ... ... ... ... | | | | 8 | 6 | 0 |
| „ Expenses of Council ... ... ... | | | | 19 | 14 | 0 |
| „ Salaries ... ... ... .. | | | | 106 | 8 | 0 |
| „ Cash in the Bank ... ... ... ... | 332 | 17 | 11 | | | |
| „ „ in the Treasurer's Hands ... | 0 | 18 | 4½ | | | |
| | | | | 333 | 16 | 3½ |
| | | | | £1,006 | 4 | 10 |

March 26th, 1902.—Examined, compared with vouchers, and found correct.

THOS. STEVENSON,
DONALD BLACK, } AUDITORS.

Messrs. Thomas Stevenson and Donald Black were thanked for their services as auditors.

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The following gentlemen were elected:—

MEMBERS—

Mr. JAMES BROWN, Duddingston Mine, South Queensferry.
Mr. JAMES DAWSON, Dullatur Station.
Mr. WILLIAM JAMES HERNAN, 26, Savoy Mansions, Savoy Street, London, W.C.
Mr. JOHN MCCULLOCH, Swinhill Colliery, Larkhall.
Mr. ALISTAIR MACKNIGHT, Brucefield, Whitburn, near South Shields.

STUDENT—

Mr. R. S. JENKINS, School of Mines, Camborne.

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## ELECTION OF OFFICE-BEARERS.

The CHAIRMAN declared the following office-bearers elected for the session 1902-1903:—

PRESIDENT.

Mr. HENRY AITKEN, Darroch, Falkirk.

VICE-PRESIDENTS.

Mr. JAMES HAMILTON, 208, St. Vincent Street, Glasgow.
Mr. JAMES HASTIE, Greenfield Colliery, Hamilton.
Mr. ROBERT THOMAS MOORE, 156, St. Vincent Street, Glasgow.
Mr. DAVID M. MOWAT, Summerlee Ironworks, Coatbridge.

COUNCILLORS.

Mr. THOMAS ARNOT, Fernbank, Newton.
Mr. DUGALD BAIRD, Lugar Iron Works, Cumnock.
Mr. ADAM BROWN, Allanton Colliery, Hamilton.
Mr. ROBERT W. DRON, 55, West Regent Street, Glasgow.
Mr. DOUGLAS JACKSON, Coltness Iron Works, Newmains.
Mr. JOHN MENZIES, Auchinraith Colliery, Blantyre.
Mr. R. D. MUNRO, 111, Union Street, Glasgow.
Mr. HENRY ROWAN, Foulford House, Cowdenbeath.
Mr. THOMAS STEVENSON, Earnock Colliery, Hamilton.
Mr. THOMAS THOMSON, Eddlewood Colliery, Hamilton.
Mr. WILLIAM WILLIAMSON, Burnblea Street, Hamilton.

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Mr. JAMES MCPHAIL was nominated for election as a Councillor in room of Mr. Michael Ross, deceased.

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Mr. JAMES HASTIE (Hamilton), in proposing a vote of thanks to the President for his services during the past year, said that they had reaped the benefit of Mr Dixon's long experience and training, which was beneficial alike to both old and young members of the Institute. The high position which Mr. Dixon had attained, was evinced by his being appointed to act on the Royal Commission, and was indicative of the excellence of his engineering education. The members hoped that Mr. Dixon might be long spared to attend the meetings of the Institute, and that he might again be elected as President.

Mr. J. S. DIXON said that it had always been a pleasure to him to advance the interests of their Institute. As he had said before, he had no doubt that the fact that this year he was officiating as President of The Institution of Mining Engineers and of this Institute, was the chief cause of his selection to serve on the Royal Commission; and he considered that it was quite as much an honour to the Institutions which he was serving as it was an honour to himself. He would always have the greatest pleasure in furthering the interests of their Institute.

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The PRESIDENT (Mr. Henry Aitken) having been introduced by the Retiring President, delivered the following "Presidential Address":—

# PRESIDENTIAL ADDRESS.

By HENRY AITKEN.

I have to thank the members for the honour which they have conferred upon me in making me President for the ensuing year. I trust that the work that will be performed by the Institute during that year will equal, if not excel, what had been done in any previous year of its existence. I feel sure that, assisted as I shall be by so able a Council as the Institute now possesses, nothing will be wanting in their efforts or mine to promote the worthy objects of the Institute.

The President's address must necessarily deal in a general way with such subjects as are most to the front at the moment, and I am thankful that it is the custom for the members to accept without criticism whatever is said by the President.

In many trades, much has been said about the need of technical education. That it is much required in many trades, and ours among the number, is not to be disputed, but the members must remember that for the most part the mine itself must be the mine manager's school and college, and unless the would-be manager educates himself in the mine, no amount of book-knowledge will ever make him capable of taking charge of a mine.

Through the kindness of our secretary, I am able to place before you diagrams (Plate VII.) shewing the total outputs of coal from the United Kingdom and Scotland from 1854 to 1901 and of Lanarkshire from 1851 to 1901 (Fig. 1); the exports of coal from the United Kingdom and Scotland from 1850 to 1901 (Fig. 2); the selling prices of coal in Lanarkshire from 1851 to 1901 (Fig. 3); and the rates of miners' wages in Lanarkshire from 1849 to and with 1901 (Fig. 3).* The diagrams speak for themselves, and it is unnecessary to make any comment thereon.

* In a report by Mr. John Grieve, of Bo'ness, engineer, and Mr. James Taylor, of Edinburgh, lapidary, made in connection with the proposed high canal to Edinburgh, dated February, 1793, the prices of coal on-the-hill at 15 collieries in Lanarkshire and Linlithgowshire are given. They vary from 5s. 10d. down to 1s. 10d. per ton, the average being nearly 3s. per ton.

So far as mining is concerned, the most important matter now in hand is the extension of the application of mining machinery to the getting of coal and other minerals. In this country, at all events, not much has been done in this direction, but there is an urgent necessity for further development, not only in applying machinery to the holing and shearing of mineral, but also in breaking it down. There is too another direction in which machinery should be applied, and that is in bringing out the coal from the face, more particularly in thin seams, to the hutches or tubs. The application of an endless band or travelling endless rope moving "slipes" would be of great advantage. Not only would this save a great amount of costly "brushing," as the walls could then be made four or five times their present length, but it would reduce greatly the expense of "backing" out the coal, and it would also reduce the loss of coal from breakage. Moreover, the output from the opened-out area would be very largely increased; and faces, which at present progress at the rate of a few feet *per annum*, might, with the use of holing and breaking-down appliances and travelling bands to move the coal along the face, advance easily over 600 or 900 feet *per annum*. Of course, such appliances can only be introduced into seams, where circumstances are favourable; but, as many such exist, there is ample opportunity for the ingenious and inventive mind to work out this subject.

The recent high price of coal has forced upon mining-engineers the necessity of reducing the amount of coal consumed at the collieries. There can be no doubt that, generally speaking, colliery-consumption is very much in excess of what it should be: and the consumption was fostered by dirty and poor material frequently coming from the mines that could not be sold, but with the present appliances for treating and washing coal this does not now apply. While, in many circumstances, the erection of new and improved plant is out of the question, great savings may be effected by attending to matters of detail with the present plant as it is, such as the proper building-in and effectual covering of boilers, steam-pipes and engine-cylinders, and the use of the condensed-steam water for boilers, where hard waters are in use, thereby preventing the great loss ensuing from scale-coated boilers. When tallow was used as a lubricant in engine-cylinders, evil results followed, as the boilers were injured and

sometimes destroyed; but when mineral oil is used in the cylinders no bad effects are experienced. The using of exhaust-steam to heat the boiler-feed water, frequent taking of diagrams to ascertain whether the valves and cylinders, etc., are in proper order, and the application of proper regulating-valves, etc., would be advantageous. By these and many other means it is not beyond the truth to state that the consumption of coal at many collieries could be reduced by about a half.

A subject that has greatly occupied the minds of coal-producers during the past year was the duty imposed by Parliament on the export of coal. The arguments used for the imposition of this tax were many, and it was very strange that all these arguments only came into existence when coal was dear. The chief reason given for the imposition of the tax was that coal in this country was being so rapidly worked out that in a very few years the whole would be exhausted, and that thereafter we should be compelled either to shiver round a peat-fire or be "nirrled" up with the heat from an American stove, fed by American coal, brought over by an American-built steamer. As regards the quantity of coal in this country still remaining to work, I think I am safe in saying that there is more workable coal known to exist in Great Britain and Ireland than was known to exist 50 years ago; and I think it not at all unlikely that 50 years hence, whoever may occupy this chair may then make the same remark. We do not know, for it has not been proved, what quantity of coal actually does exist in this country, but we do know that there are probabilities, if not certainties, that great areas of workable coal, unproved at present, will be available in the future. When we look beyond Great Britain and Ireland, we find that in the rest of the world the estimated quantity of available coal has increased many thousandfold during the last fifty years. In every country, from the equator to as near the poles as we have been able to reach, coal has been found in such enormous quantities that our own coal-fields are almost insignificant by comparison; and when we consider how cheaply coal can now be carried by sea, and how every year this cost is being reduced, the chances of our suffering from a want of heat and light for many generations to come are small indeed.

Another reason given for imposing this tax was that the free export of coal enabled the foreigner to manufacture goods, and

compete against us in foreign markets and even in our own markets here. This no doubt is true, but as these foreigners have ample coal of their own, it is only a question of time when their developments will equal their requirements, and then they will not need our coal. In this connection, and particularly considering the advantage derived from securing a profit when you can, and so making capital from which to derive interest, I call to memory an incident which happened about 35 years ago when we were working coal round the march of a neighbouring property. I offered the owner what he then considered a very handsome royalty-rent for it; however, he declined to accept it; but his heirs let this field a few years ago. A comparison of the two bargains shewed that, if he had taken my offer, the royalty-rents with interest would now have become £40,000, whereas his heirs will only draw a little over a fourth of this amount.

In almost every country in the world, the development of coal is being carried on at a rate far in excess of what even this country is doing, and not only are they supplying their own wants, but many of them are competing against us in several markets. The higher the tax placed upon the export of coal, the sooner will the foreigner develop his coal-fields to meet his full requirements. Within a month, I have had applications from abroad to assist in raising capital for four new collieries that are estimated to contain 750,000,000 tons, and these are but patches in four different enormous coal-fields in three different parts of the world. For instance, take China, which contains immense coal-fields. Mr. A. Reid, in a paper read before the Midland Institute of Mining, Civil and Mechanical Engineers in February last, speaking of the Shansi coal-field, repeats what was said at a meeting of one of the sections of the British Association at Bradford in 1900, that "It is estimated that the deposits are so immense, that they could supply the world's demand for fuel at the present rate of consumption for the next 2,000 years."*

It is to be remembered that, nowadays, coal is not the only article from which heat, light and power may be produced. Fifty years ago, who dreamed of the oceans of oil that lie beneath the earth's surface in many parts of the world; or thought of the many enormous magazines of natural gas belowground; or could have

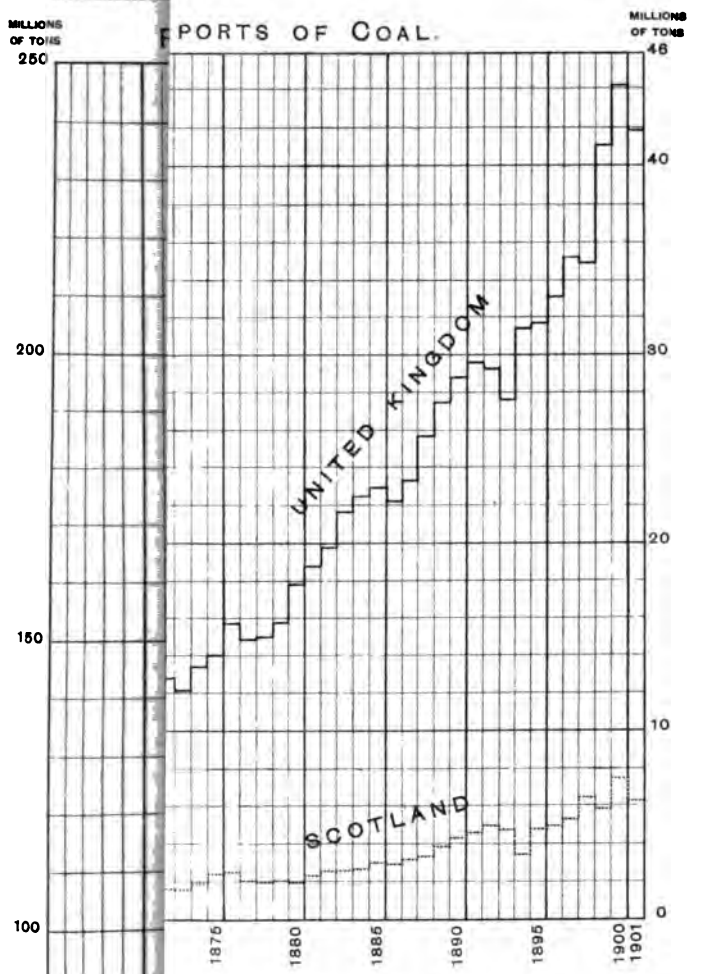
* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 30.

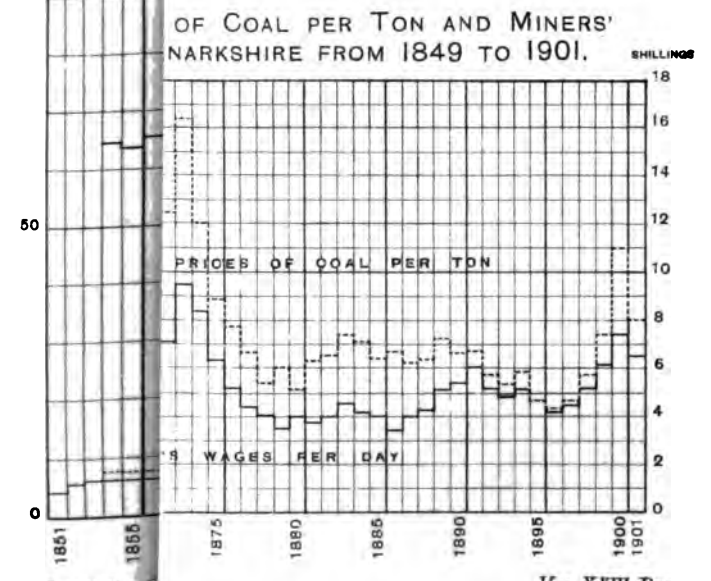
conceived that it would be possible to convert the mighty power in the waterways and waterfalls of the world, and send it wherever heat, light and power were required?

I ask whether the members of Parliament, when they allowed this tax, realized that it would have the effect of partly stopping the exportation of coal and thereby throw more coal on the home market than it could take, and that prices would be reduced all round. If so, they passed a measure to enable the majority to buy cheap coal at the expense of the minority.

The Chancellor of the Exchequer will obtain one shilling a ton for every ton of coal exported, and he may receive, say, £1,750,000 or £2,000,000 per annum, but he should remember that the coal-trade suffers by having the sources of supply restricted and its markets glutted. Some Governments do all they can to foster home-industries and retain population in the country. Our Government, whatever they may do with other industries, are doing the coal-trade great harm. The Chancellor of the Exchequer should also bear in mind that, if he either brings about a reduction upon the amount of coal formerly exported, or reduces the amount which would have naturally been attained by normal expansion, the ratio of which is shewn in Fig. 2 (Plate VII.) he has committed a grave mistake. He should have known that every ton of coal exported, when costs, railway-dues and freight are added together, means an addition to the wealth of this country of about £1 per ton. How far this coal-export tax has led to the present congested state of the trade I am not prepared to say, but that its effect has been bad is beyond question. Broadly, the outcome of this tax will be that owners will have to accept less for their coal, and the miners will either get less work or less wages, and possibly both.

Over and above it should be kept in mind that our bad example may be followed by other nations, who might place taxes upon the export of materials which are essential to us and so cause great loss to this country. I venture to assert that for every shilling that the Chancellor of the Exchequer receives from the tax the coal-trade suffers, directly and indirectly, a loss of 5s. Not for one moment should it be thought that the coal-trade is not in the very fullest sympathy with the Government in its present efforts, but I do object to taxation that is working and will continue to work to the great detriment of trade.


PORTS OF COAL.
MILLIONS OF TONS
250
200
150
100
50
0
MILLIONS OF TONS
46
40
30
20
10
0
UNITED KINGDOM
SCOTLAND
1851
1855
1875
1880
1885
1890
1895
1900
1901


OF COAL PER TON AND MINERS'
NARKSHIRE FROM 1849 TO 1901.
SHILLINGS
18
16
14
12
10
8
6
4
2
0
PRICES OF COAL PER TON
'S WAGES PER DAY
1875
1880
1885
1890
1895
1900
1901

Even in so serious a matter, a farcical element is present, as the Government have appointed a Royal Commission to ascertain whether they have done right in imposing this tax. Truly unwisdom dwells not in Scotland alone. It would have been more to the purpose, in place of spending time and money on this Royal Commission, if the Government had drilled twenty or thirty deep bore-holes, after making proper arrangements with the land-owners round such bore-holes.

The coal-tax, viewed from whatever standpoint one may choose, morally, practically, financially or politically, is a great mistake, and one that should never have been passed by the Parliament of the United Kingdom of Great Britain and Ireland.

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Mr. R. T. Moore (Glasgow), in proposing a vote of thanks to the President for his address, said that Mr. Aitken, who was one of the oldest coal-masters in Scotland, was a deep thinker and viewed matters from an original standpoint. He had the faculty of throwing a new light on subjects of which they had get into the habit of thinking, that their old views were the only possible ones. He (Mr. Moore) had been interested in the President's remarks relating to the quantity of coal remaining unwrought in this country, as he had always thought that too much was made about the exhaustion of our coal-fields. They had 200 years' supply of coal remaining in this country, and that, assuredly, was a long time. It was only within the past century, that they had made use of coal so extensively as they were now doing, and with the prospect before them of 200 years' supply, succeeding generations would have abundance of time to find out a substitute for coal.

The vote of thanks was cordially approved.

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## DISCUSSION OF MR. JAMES BARROWMAN'S PAPER ON "WHAT IS THE LEAST POSSIBLE WASTE IN WORKING COAL."*

Mr. James Hastie observed that Mr. Barrowman had commented on the general saving that had taken place, but he had omitted to state when and where that saving commenced in the different seams worked.

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 55.

The PRESIDENT (Mr. Aitken) remarked that the specific gravity of coals varied very much: he had known parrot-coal to vary from 1·08 to 1·50; and as to common coals, he had known them vary within 750 to 1,000 feet from 1·2 to 1·4. In Lanarkshire, however, the coals were much more regular.

Mr. JAMES S. DIXON (Glasgow) said that he had recently had occasion to make two calculations of a similar kind to those made by Mr. Barrowman. One was of an extensive longwall working, which had gone on for a period of 10 years with a production of 3,000,000 tons, and he found that the disposals exceeded the calculated quantity by about 2 per cent.; the other was a stoop-and-room working, and the disposals were over about ¼ per cent. less. These two examples corroborated Mr. Barrowman, and they were even better than his calculations. The actual specific gravities were used in these calculations, and in one, it was 128 tons and in the other 126 tons per inch per acre. He had found in his experience that the specific gravity of the coals of Lanarkshire did not vary much, as compared with other coals in different parts of the country: in South Wales, he understood that the density of the coal varied 25 per cent.

Mr. R. W. DRON (Glasgow) remarked that Mr. Barrowman said "that we may conclude, from the figures shown, that the progress of mining science during the last 30 years has resulted in a reduction of the unavoidable waste or loss in working from 10 to about 5 per cent., or, more probably, 2½ per cent."* He (Mr. Dron) thought that, before engineers could claim credit for this advance in mining science, they must pay very careful attention to the data upon which that claim was based. The Royal Commission, as Mr. Barrowman pointed out in his paper, were dealing with very doubtful data, when they made this estimate of 10 per cent. This conclusion was not reliable, according to the statements made by some of the witnesses. On the other hand, Mr. Barrowman was dealing with careful and accurate statements, on which he could absolutely rely. In his (Mr. Dron's) opinion, if Mr. Barrowman had 30 years ago made as close an examination of similar collieries as those now examined, he would have found that the loss in working was not 10 per cent. It might

* *Trans. Inst. M.E.*, vol. xxiii., page 62.

have been 5 per cent., or a little more than it was at the present time; but he thought that they were claiming too great an advance on the work of their fathers.

The quotation from the report of the Royal Commission on Coal reads that "under favourable systems of working, the unavoidable loss is about 10 per cent."* It seemed to him (Mr. Dron) that "under favourable systems of working" referred to systems of working suitable to the particular nature of the coal-seam, and had no reference to favourable conditions such as applied to the system being discussed; and that "favourable systems" applied to such collieries as Mr. Barrowman had comprised in his paper.

The PRESIDENT (Mr. H. Aitken) said that in his young days, in working mines under the stoop-and-room system they could only generally go from six to nine months, when they had to stop working, draw the rails and abandon the mine; and more coal was left in the stoops than they had worked altogether.

Mr. R. T. MOORE (Glasgow) remarked that while Mr. Barrowman's paper was a most excellent one: it was a statement of fact and did not, therefore, lend itself readily to discussion. He noted, however, that the collieries selected, were situated in the best district of the coal-field. They were free from troubles; the seams were of moderate thickness, lying almost level, the roofs and pavements were good and altogether the circumstances were possibly the most favourable in Scotland for the complete exhaustion of the seams. The 10 per cent. of loss in working mentioned by the Royal Commission, was an estimate for the most "favourable systems of working" applied to all the seams of the country. Had Mr. Barrowman included in his estimates the most "favourable systems of working" of steep seams in troubled fields with bad roofs and pavements very probably his figure of 2½ per cent. loss would have been considerably increased and though, no doubt, improvement had been made he did not think it was quite fair to state that the 2½ per cent., shown as the result of Mr. Barrowman's calculations, corresponded with the 10 per cent. indicated by the Royal Commissioners in their report as the probable loss in working.

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 55.

The Royal Commission noted that coal was lost owing to irregular boundaries, and to difficulties in getting wayleaves. It seemed to him that their mining laws were defective compared with those in other countries, and it was desirable that there should be some court to which difficulties of this kind should be referred. Coal was a national property, and they were all anxious that it should not be lost to the nation by obstructive landlords, who at the present time could block the way by saying "you shall not have a wayleave through my property." In other countries, the mineral tenants had a right to draw minerals through other lands on paying the damages caused by their operations and he thought they should have similar powers here.

Mr. James S. Dixon said that he did not quite concur with the remarks made by Mr. Dron and Mr. Moore, as he thought that when the Royal Commissioners of 1871 made their report, they had before them what was at that time the most favourable system of working. He thought that Mr. Barrowman was perfectly justified in the conclusions at which he had arrived. The 10 per cent. of loss, contrasted with Mr. Barrowman's 0·11 per cent. in longwall working, showed that they had made a vast advance on the methods of 30 years ago.

Mr. James Hastie (Hamilton) stated that 30 years ago it was a well-known fact that miners hewing coal in longwall and stoop-and-room were filling dirt along with the coal. Instead of the purchaser in the market getting 20 cwts. of coal in the ton, he would receive what would probably now amount to 18 cwts. of washed coal.

Mr. James Hamilton (Glasgow) did not think that Mr. Barrowman's results should be compared with those of the Royal Commissioners of 1871, because any calculation which might have been made in Hamilton district 30 years ago would have been higher than now. He had the curiosity to try an area of 5,000 acres, and he found that the loss arising from barriers and faults was about 15 per cent.

Mr. James Barrowman, replying to the discussion, said with reference to Mr. Hastie's remark as to when the improvement began, that it did not begin at any particular time. They were always improving, and had been improving gradually during the

last 30 years. Of course, since coal-washing machines had come into general use, the coal which was sent to the market was cleaner than it used to be. He was a little surprised at the remark made by the President as to the variation in the specific gravity of coals. When he was surveying he always took the specific gravity of the coal of each seam surveyed, and he found on looking at his notes that the variation, so far as it referred to the coal-seams of the Lanarkshire district, was very small. The lightest common coal that he knew of was the Kilsyth coking-coal, and the heaviest common coal was the Splint coal which used to be worked in the neighbourhood of Barrachnie. These were the two extremes: the lowest being about 121 tons, and the other about 132 tons, per inch per acre. He did not agree with Mr. Dron's remarks, about the loss 30 years ago, as he was satisfied that it was more than 10 per cent. in this district. He agreed with Mr. Dixon, that the 10 per cent. referred to by the Royal Commissioners of 1871 as the probable working-loss, was not applicable to the whole country, but applicable only to particular cases where the systems worked were favourable.

He had made the following calculations, in order to reply to the suggestion that the conditions of working were better now than they were 30 years ago:—The produce of ten collieries working the seams referred to in his paper during the years 1896, 1897 and 1898 was 4,615,068 tons; the excavations as measured were calculated to produce 4,607,905 tons. This shewed an excess of production over measurements of 0·16 per cent. For the three succeeding years, 1899, 1900 and 1901, eight of these ten collieries produced 5,019,992 tons; the excavations in this case were calculated to produce 5,134,415 tons, shewing a deficiency of production of 2·2 per cent. Throwing these two quantities together, the result is 1·1 per cent. of deficiency of production, as compared with measurements. While these figures were satisfactory and the calculations carefully made, he placed more reliance upon those given in his paper; but, so far as they went, they showed that the loss during recent years has been very small indeed.

The discussion was adjourned.

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The SECRETARY read the following notes on "Slips in a Sand-bank":—

# SLIPS IN A SANDBANK.

By JAMES BARROWMAN.

Fig. 1 represents a section of sand in the sand-quarry a Chatelherault Park, near Hamilton. The lines of stratificatio are clearly marked, owing to the succession of clayey bands in th bank, the loose sand having been blown away by the wind, leavin the clayey bands outstanding.

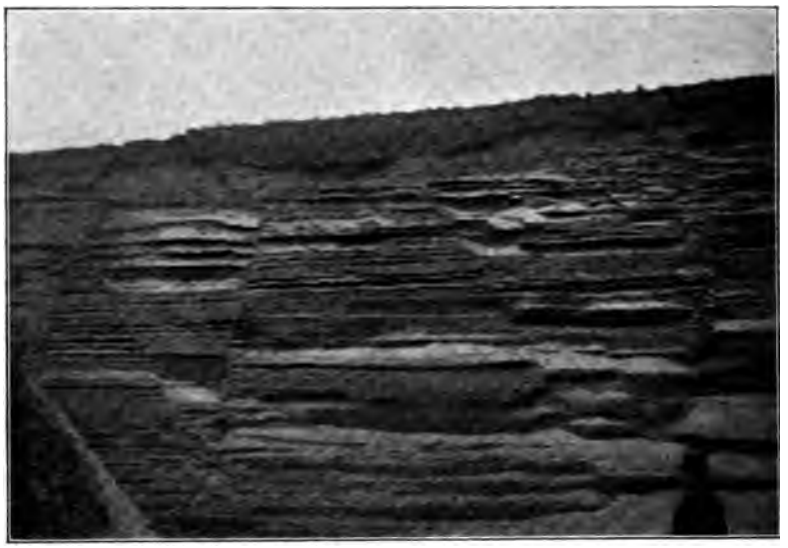

Fig. 1.—Sand-quarry near Hamilton.

The lines of slips are also clearly seen from the same cause The longitudinal extension of the slips is small. When th photograph was taken, about 6 months ago, there was no indica tion of the slips in the opposite side of the quarry about 50 fee distant. Since then the bank had been worked off for about 3( feet, but the slips are not now visible on the face.

The height of the bank is sufficiently indicated by a comparisor with the height of the figure in the foreground.

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Mr. James Baird's "Description of Underground Haulag at Mossblown Colliery, Ayrshire," was read as follows:—

# DESCRIPTION OF UNDERGROUND HAULAGE AT MOSSBLOWN COLLIERY, AYRSHIRE.

By JAMES BAIRD.

*Introduction.*—The subject of the conveyance of coal underground from the working-face to the pit-bottom is one which demands careful consideration and attention in all mines, whether this be done by manual, horse or mechanical power. In extensively worked mines it is necessary that mechanical haulage be adopted, if large outputs at a minimum of cost be desired. Conditions vary so much at every colliery that no definite style of haulage can be said to be the best; so that it rests with the management of each colliery to adopt the system which they may think best suited to the circumstances by which they are surrounded.

Where the roadways can be driven straight, and the roof is strong enough to admit of a double road being driven, it is generally admitted that the endless-rope system is more economical than main-and-tail rope, and with longer roads this is the more noticeable.

With pits being sunk to the deeper seams (and the consequent increased cost of working, combined with the erection of extensive and costly cleaning-and-separating plant) the present tendency is to extract the coal from larger areas than has been the practice heretofore; and the question of efficient mechanical haulage then becomes one of first importance.

The following paper describes the system of endless-rope haulage adopted at the Mossblown pits of the Auchincruive Coal Company, and the accompanying plans and sections will render it clear to everyone interested in the subject.

*Colliery.*—Mossblown is a new colliery, the first sod having been cut so recently as May, 1897. Two pits, 45 feet apart, have been sunk 600 feet to the Splint coal-seam. The most recent

coal-cleaning machinery has been erected for the efficient handling of a large output, which, after full development, is expected to reach 1,000 tons per day, but at present it is 700 tons. Of this output, 400 tons are hauled to the pit-bottom out of three main roadways, AIE, AH and AK, of No. 1 pit (Fig. 1, Plate VIII.) by endless-rope; and, as time goes on, this quantity of course will be greatly increased, without materially raising the present cost per ton hauled.

*Haulage-engines.*—On the surface, situated between the two pits and below the pit-head scaffolding, is the horizontal haulage-engine, having two cylinders, each 14 inches in diameter by 24 inches stroke, fitted with helical-teethed wheels in the ratio of 6 to 1. On the hauling-shaft is keyed a Clifton wheel, 7 feet in diameter, fitted with renewable chilled-iron segments having an inclined face of 1 in 6½, to enable the rope to slip easily and to run free. This engine (Fig. 2, Plate VIII.) is fitted with expansion-valves, which can be adjusted at will. At present, the steam is cut-off at half stroke. A Pickering governor is used, fitted with automatic stop-gear, so that in the event of the governor-belt breaking, the steam is immediately cut off.

Steam is raised in four Lancashire boilers, 30 feet long by 8 feet in diameter, at a pressure of 100 pounds per square inch, but it is reduced to 65 pounds, before reaching the engine, by being passed through an Auld reducing steam-valve—drier steam being thus produced.

*Band-rope.*—The band-rope is passed 3½ times round the Clifton wheel, *a*, on the hauling-shaft, then led over two rope-wheels, *b*, 5 feet in diameter, placed at the pit-top (Fig. 3, Plate VIII.), run down the shaft uncased, round two rope-wheels, *c*, 5 feet in diameter, at the pit-bottom, and then led along the roof, supported on wheels and rollers, to the central vertical shaft, *d*, 9 feet long and 8 inches in diameter, placed about 150 feet from the pit-bottom (Figs. 3, 4 and 5, Plate VIII.).

On this vertical shaft, *d*, are placed four Clifton wheels, 7 feet in diameter, similar in every respect to that which is placed on the hauling-shaft of the engine. The driving-wheel, round which the band-rope passes 4 times, is keyed at the top of the shaft. The remaining three Clifton wheels, running loose on the

shaft, are each fitted with a friction-ring, 3½ feet in diameter, and are readily manipulated by one person, who can have them all working simultaneously or independently one of the other, in as many haulage-roadways (Figs. 6 and 7, Plate IX.).

The band-rope is 1,800 feet long and 1 inch in diameter, made of best improved galvanized steel, consisting of 6 strands of 7 wires each of No. 11½ Birmingham wire-gauge. It travels at the rate of 1¾ miles per hour, and is kept taut on the empty side of the rope by passing round a wheel on a tension-carriage and a back-balance (Figs. 4 and 5, Plate VIII.).

*Main Level Haulage-road.*—The main level haulage-roadway, AIBCDE (Fig. 1, Plate VIII.), is 2,400 feet long, with a cross-section of 8 feet by 6 feet inside the timbering. Two lines of rails are laid of 2 feet gauge, with a space of 1 foot 4 inches between the full and empty roads. This roadway, IM, has been driven perfectly straight; and, as the longitudinal section (Fig. 8, Plate IX.) shows, it is of an undulating character.

The haulage-rope, ¾ inch in diameter, is made of improved steel, consisting of 6 strands of 7 wires each of No. 13¾ Birmingham wire-gauge. It is run under the tubs and in the middle of the road. Cast-iron rollers, 9 inches long by 4 inches in diameter, running in cast-iron grease-pedestals, are placed every 45 feet or thereabouts, to carry the rope and to reduce friction. The speed of the haulage-rope is the same as that of the band-rope, namely, 1¾ miles per hour.

The tub is attached to the rope by means of Smallman clips, No. 3 size. The hutches are placed at intervals of 45 to 60 feet, or thereabouts, along the rope, and are attached and detached without the rope being stopped.

The gauge of the roads is 2 feet, and as it is imperative for the successful working of an endless-rope haulage of any importance to have good, substantial and well-laid rails, steel bridge-rails, weighing 20 pounds per yard, in 10 feet lengths, have been adopted, and all the joints are fish-plated (Fig. 13, Plate IX.).

To keep the rails in proper alignment, deals, 9 inches wide, 3 inches thick, and of the full breadth of the roadway, have also been used, where necessary, to assist the ordinary fir-sleepers, 3 feet long, 6 inches wide and 2 inches thick, and the rails are nailed and fish-plated to these. The proper gauge and distance between the full and empty roads are thus maintained.

Hanging-on stations can be made as often as is found necessary, but the fewer the better, compatible with the proper distribution of the work, as every station necessitates a man, or a man and a boy, to hang-on the full hutches, to clip-off the empty hutches, and to regulate the traffic; and to multiply these stations, unnecessarily, would entail increased cost.

Branch-roads can be connected to the main haulage-road either by crossings and cut rails, or by flat plates, laid between the rails with a space left for the rope to run through. If crossings are used, it is better to lay them in such a way as to avoid the use of facing-points, as these are apt to cause the tubs to leave the rails, and bring about stoppages.

*Signals.*—The signalling is effected by electric bells and wet batteries. Two bare galvanized-iron wires are carried along the full length of each of the haulage-roadways, and are supported on insulators fixed on wooden horizontal arms attached to the side-props. A separate bell from each haulage-roadway is erected at the central station, *d* (Fig. 4, Plate VIII.). Each bell is rung by bringing the two wires together, and by this means the whole of the haulage-ropes are controlled by one man, at the central station, *d*; on hearing the bell ring he throws in, or out, as required, the friction-clutch of the haulage-road corresponding to the bell so rung.

To further assist in this direction, a third wire is run along the same wooden arms for telephonic communication; and, in the event of a stoppage taking place, the officials can locate or learn the cause, and, if necessary, despatch men to remedy the same with the minimum loss of time. This telephonic system is also carried up the shaft to the weighing-office on the pit-bank, and is there under the control of the pit-headman. At present, it is only possible to speak from or to the various termini; but by having a pocket-telephone it is possible to open up communication from any part of the haulage-roads. As the haulage-roads have increased in length, the necessity for telephonic communication has made itself increasingly felt.

*Electric Lighting.*—For the safer and more expeditious handling of the traffic at the pit-bottom, electric light has been introduced in all the roadways leading to and from the pit-bottom, for a distance of 160 feet.

*Clip-off Spot.*—Fig. 4 (Plate VIII.) shows the general arrangement at the pit-bottom, and the section (Fig. 3) shows the arrangement of the roads from the clip-off to the pit-bottom. As all the haulage-roadways are arranged in the same manner, a description of one will be sufficient.

At the point, *e* (Figs. 3 and 4), the full hutches are detached from the haulage-rope, 130 feet or thereabouts from the pit-bottom, from which point, *e*, they run by gravity to the pit-bottom; likewise the empty hutches return from the pit-bottom to the point, *f*, and are there attached to the ingoing haulage-rope. The gradient of the full-hutches road from the clip-off spot, *e*, to the pit-bottom is 1 in 100, and the gradient of the empty-hutches road from the pit-bottom to the hanging-on spot, *f*, is 1 in 75.

In the event of a temporary stoppage of the winding, three loaded-hutch roads, *g*, *h* and *i* (Fig. 4), can be filled with loaded hutches. As many as 60 hutches can be so collected before the haulages need be stopped. This storage-room is often a great advantage, more especially where the winding is not up to its maximum quantity. At the point, *j* (Fig. 4), switches are placed for guiding the empty hutches into either the main level haulage-road or into the main dook haulage-road as may be found necessary, the hutches for the latter section being run below the full-hutches road of the former section.

*Main Dook Haulage-road Terminus.*—At the present terminus of the main dook endless-rope haulage, L (Fig. 1, Plate VIII., and Fig. 11, Plate IX.), there has been fitted on the same shaft as the return-wheel (which in this case is a Clifton wheel, 5 feet in diameter, fitted with renewable steel-segments having an inclined face of 1 in 6½), a drum, *k*, 5 feet in diameter and 1 foot 6 inches wide, lagged with ½ inch steel-plates. It is made to run loose on the shaft, and is fitted with a friction-clutch, 2½ feet in diameter, and brake-gear (Figs. 14, 15, 16, 17 and 18, Plate X.).

The main dook endless haulage-rope acts, in this case, as the band or driving-rope for transmitting power to this drum. On this drum is wound 600 feet or thereabouts of ½ inch rope, made of improved steel-wire, consisting of 6 strands of 7 wires each of No. 16 Birmingham wire-gauge. This rope is utilized for drawing material from the extending dook, LH (Fig. 1, Plate VIII.), an arrangement which abolishes to a large extent what has proved

to be very heavy work for horses, the inclination being 1 in 6 or thereabouts.

The dook will be driven 600 to 1,200 feet in this way or even farther, if it be found expedient to do so; although it is intended to shift the Clifton wheel and drum every 600 feet or so, and to extend at the same time the endless-rope haulage by the same length. And at these points, levels will be broken away right and left of the dook, and the coal worked to the rise from them.

The speed of the single rope is the same as that of the endless rope, although it could be increased, if found desirable, by gearing or by making the drum larger than the Clifton wheel; but as the rope will only be used for developing the two leading places, it is scarcely necessary to increase the speed beyond 1¾ miles per hour. A train, consisting of 3 or 4 hutches, is drawn up at a time and landed at the hanging-on spot of the endless rope at the point L (Fig. 1, Plate VIII.), and the drum thus acts as a feeder or secondary haulage thereto.

*Slope Dook.*—The same arrangement, as that described in the foregoing paragraph, is placed at the point K (Fig. 1, Plate VIII., and Fig. 12, Plate IX.) in the slope dook endless-rope haulage.

*Self-acting Endless-rope Incline.*—Fig. 9 (Plate IX.) is a section of a self-acting endless-rope incline, 1,200 feet long, and Figs. 19 and 20 (Plate X.) show the arrangement of the terminal wheels. The top wheel, *l*, is an ordinary rope-wheel, with a brake-rim attachment, and a brake-strap, which is manipulated by a screw and a hand-wheel. The rope is passed 1½ turns round this wheel. At the foot of the incline is the return-wheel, *m*, mounted on a movable tension-bogie, which in turn is weighted by a back-balance.

The full hutches going down the incline draw up the empty hutches. The person in charge at the top of the incline manipulates the brake, and thereby regulates the speed of the rope. The dip-and-rise of this road is 1 in 11 or thereabouts. This style of haulage will not run on gradients of less than 1 in 20.

This rope, CG, acts as a secondary haulage to the main level haulage-road and is a feeder thereto, as is also the dook-road, EF, (Fig. 10, Plate IX.). In this latter road, however, the haulage

is effected at present by horses, but ere long this will be replaced by endless-rope haulage, the power for which will be transmitted through the main level endless-haulage rope.

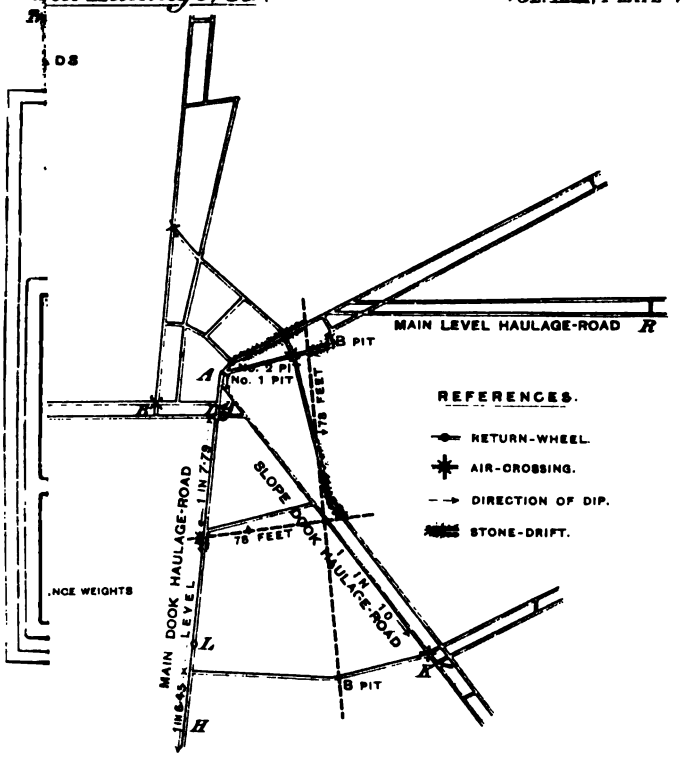
The length of this dook will ultimately be more than 1 mile measured from E (Fig. 1, Plate VIII.), where it is intended to erect a vertical shaft similar to the central shaft at *d* (Figs. 6 and 7, Plate IX.) fitted with 4 Clifton wheels, namely, 1 fast wheel and 3 loose wheels, each fitted with friction-clutches, for working endless haulage-ropes in the level road, EM, the inbye-dook, EF, and the rise-road, EN (Fig. 1, Plate VIII.).

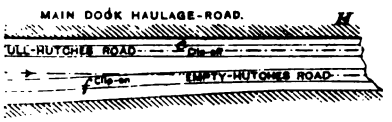
*Future Developments.*—In the near future it is also intended to alter the gearing of the haulage-engine (Fig. 21, Plate X.), from a gear of 1 in 6 to 1 in 12, and to run the engine at a speed of 84 strokes per minute instead of 42 as at present, and by this means the power of the engines will be doubled. Two loose Clifton wheels, 7 feet in diameter, of the same pattern as those previously described, will be placed on the driving-shaft of the engine, and each will be fitted with a friction-clutch 3½ feet in diameter. One will be used for the present haulage in No. 1 pit, and the other for the proposed haulage in No. 2 pit. In this latter case, a band-rope will not be used at first. The ¾ inch haulage-rope would be passed 3½ times round the Clifton wheel on the engine-shaft, over the rope-wheel, 5 feet in diameter, placed over No. 2 pit, then down the shaft, round the rope-wheel, 5 feet in diameter, placed at the bottom of the shaft, round a tension bogie, then led in the main haulage-road to the return-wheel, R (Fig. 1, Plate VIII.) and back to the engine. This arrangement would necessitate a person being placed in charge of the haulage-engine on the surface, to work the clutch for No. 2 pit.

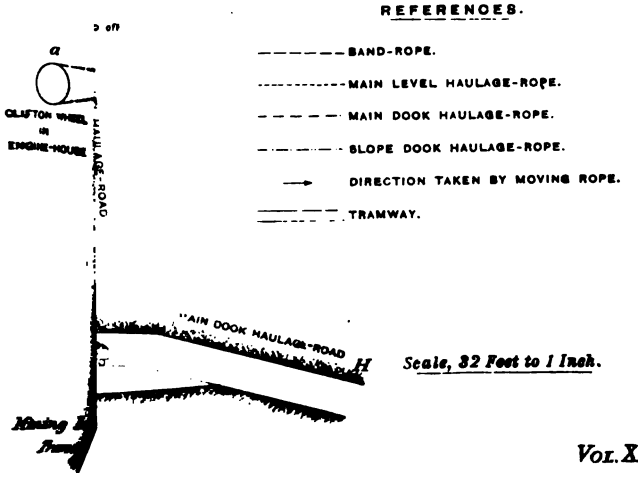
*Conclusion.*—From the foregoing description and the plans submitted it will be readily understood that this style of rope-haulage is more adaptable for hauling material from any or all corners of a pit than any other method of mechanical haulage; and at the same time it can be worked more cheaply, although the initial cost is comparatively heavy. The labour-cost of haulage is at present 1·11d. per ton.

Figs. 22 and 23 (Plate X.) represent the hutch in use.

The following conspectus of prices may be useful:—The hauling-engine (Fig. 2, Plate VIII.) including erection, cost £375; and the additional gear, including erection, cost £330; making the total cost of the engine, £705. The vertical shaft and iron framing, Figs. 6 and 7 (Plate IX.) excluding erection, cost £310. The Clifton wheel and drum, at the bottom of the dook-haulage, including three rope-wheels (4 feet in diameter) and one rope-wheel, 5 feet in diameter (Figs. 16, 17 and 18, Plate X.), erection excluded, cost £120. Smallman No. 3 wire-rope clips, cost 9s. 6d. each. The haulage-ropes cost £1 8s. per cwt.


MAIN LEVEL HAULAGE-ROAD
R
No. 2 PIT
No. 1 PIT
A
REFERENCES.
RETURN-WHEEL.
AIR-CROSSING.
DIRECTION OF DIP.
STONE-DRIFT.
SLOPE DOOK HAULAGE-ROAD
1 IN 7·73
78 FEET
MAIN DOOK HAULAGE-ROAD
LEVEL
1 IN 6·43
1 IN 10
HAULAGE-ROAD
L
H
K
PIT
BOGIE
ROPE
STATION


MAIN DOOK HAULAGE-ROAD.
H
ULL-HUTCHES ROAD
EMPTY-HUTCHES ROAD


REFERENCES.
BAND-ROPE.
MAIN LEVEL HAULAGE-ROPE.
MAIN DOOK HAULAGE-ROPE.
SLOPE DOOK HAULAGE-ROPE.
DIRECTION TAKEN BY MOVING ROPE.
TRAMWAY.
a
CLAYTON WHEEL
IN
ENGINE-HOUSE
HAULAGE-ROAD
MAIN DOOK HAULAGE-ROAD
H
Scale, 32 Feet to 1 Inch.

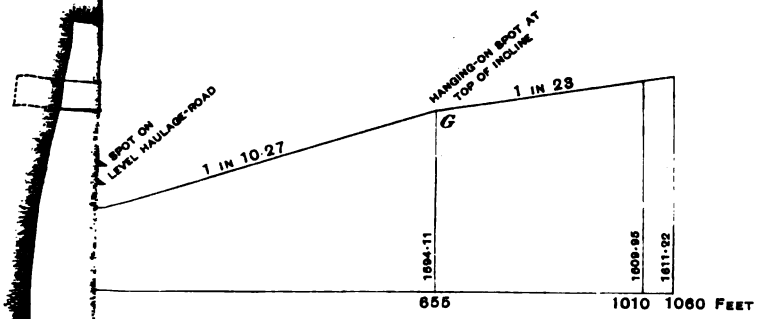



FIG. 9.—SECTION OF SELF-ACTING ENDLESS-ROPE INCLINE.

*Horizontal Scale, 330 Feet to 1 Inch.*

*Vertical Scale, 100 Feet to 1 Inch.*

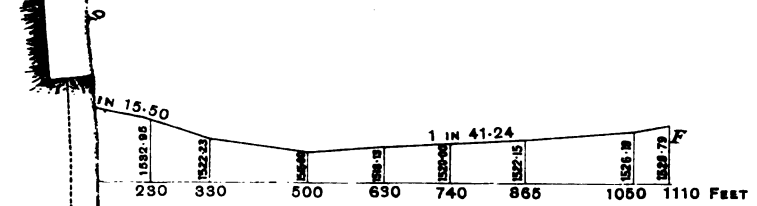
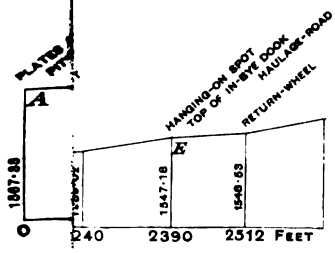



FIG. 10.—SECTION OF IN-BYE DOOK HAULAGE-ROAD.



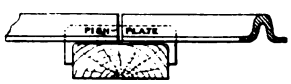
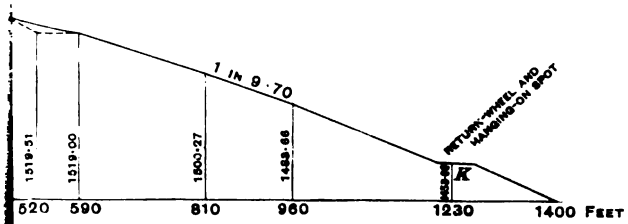
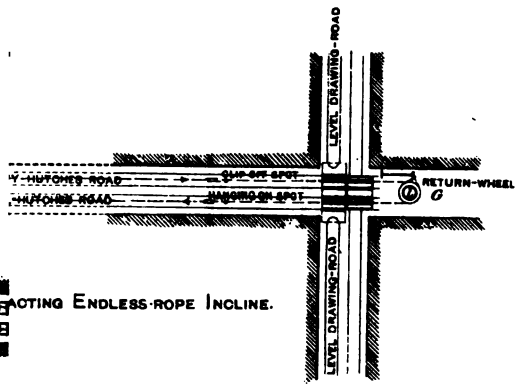




FIG. 13.—ELEVATION SHEWING METHOD OF FISH-PLATING BRIDGE-RAILS.

*Scale, 1 Foot to 1 Inch.*

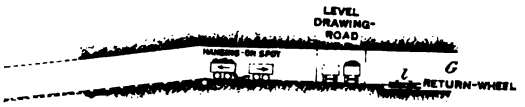



SECTION OF SLOPE DOOK HAULAGE-ROAD.




ACTING ENDLESS-ROPE INCLINE.

Fl 2 Feet to 1 Inch.




NG ENDLESS-ROPE INCLINE.

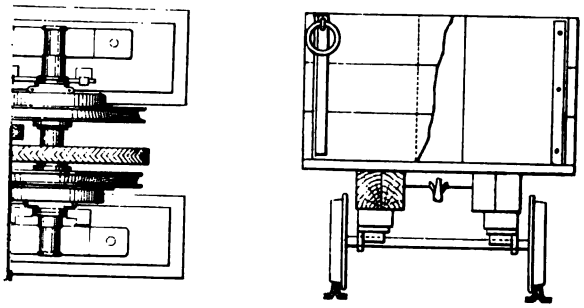


FIG. 22.—END-ELEVATION OF HUTCH.

Scale, 2 Feet to 1 Inch.

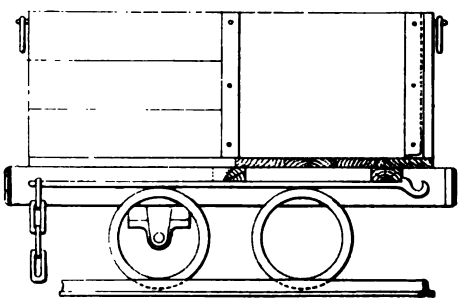


FIG. 23.—SIDE-ELEVATION OF HUTCH.

# NORTH STAFFORDSHIRE INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE GRAND HOTEL, HANLEY, MAY 12TH, 1902.

MR. W. N. ATKINSON, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected:—

MEMBER

Mr. JOHN BRADBURY, Engineer, North Staffordshire Railway Company, Stoke-upon-Trent.

ASSOCIATES—

Mr. WILLIAM COATES, Colliery Fireman, Norton Green, near Smallthorne.
Mr. J. W. FROST, Engineer, Glebe Colliery, Fenton.
Mr. S. HOLLINSHEAD, Colliery Fireman, Norton, near Smallthorne.
Mr. S. MILLINGTON, Colliery Fireman, Sneyd Green, Burslem.
Mr. THOS. PARKINSON, Engineer, Sneyd Colliery, Burslem.
Mr. J. H. RONTREE, Under-manager, Foxfield Colliery.
Mr. JAMES SHERWIN, Underlooker, Smallthorne.

STUDENT—

Mr. LAURENCE CLIVE, Clanway House, Tunstall.

## AWARD FOR PAPER.

The PRESIDENT stated that a prize had been awarded to Mr. J. T. Stobbs for his valuable paper on "The Correlation of the Coal-seams of the North Staffordshire Coal-field."

## DISCUSSION OF MR. W. E. GARFORTH'S PAPER ON AN "EXPERIMENTAL GALLERY FOR TESTING LIFE-SAVING APPARATUS,"* AND MR. M. H. HABERSHON'S PAPER ON "A JOINT COLLIERY RESCUE-STATION."†

The PRESIDENT (Mr. W. N. Atkinson) remarked that very little had been done with respect to the institution of rescue-stations. He thought that the formation of one had been commenced in Yorkshire, and that was the only station which had been started, although the subject had been discussed for several years. The experiments at the testing-gallery erected by Mr. Garforth at Altofts were very interesting, and they brought out the difficulties connected with the use of the pneumataphor life-saving apparatus. To a certain extent, perhaps, people who saw the experiments might not have so favourable an impression of that apparatus as it really deserved, because in an experimental station they could not have all the conditions existing in a mine; and cases might arise in which the conditions in a mine would be more favourable than in the experimental gallery. Besides saving life, this apparatus might also be useful in saving property in cases of fire. Some people might think that colliery-owners and managers were neglecting opportunities of saving life if they did not provide these appliances, but anybody who saw the experiments and knew the conditions under which they could be used in mines, would speedily recognize that the apparatus could only be used for saving life under very exceptional circumstances.

Mr. A. M. HENSHAW said he had witnessed the experiments at Altofts colliery, and he had learnt something as to the desirability of keeping the pneumataphor in readiness in mining districts, and the use of the apparatus in cases of emergency would be a step in the right direction. There was no doubt that the apparatus was most useful as far as it went, because unfortunately hardly any district was free from some kind of disaster; and he agreed that there should be general stations in every district where a few suits of the pneumataphor apparatus and Meyer helmets could be kept, and a few men at each colliery should be

* *Trans. Inst., M.E.*, 1901, vol. xxii., pages 169 and 192; and vol. xxiii., page 37.

† *Ibid.*, 1901, vol. xxi., page 100; and vol. xxii., page 195.

trained to use them. The apparatus would be at hand when needed; and he could quite conceive that in almost any explosion or gob-fire or accident such an apparatus might save life and property. At Talk-o'-the-Hill colliery, they had used the pneumataphor in the case of a gob-fire, which lasted seven weeks, and although they had not to use it for life-saving, they found the apparatus very useful in re-opening the mine after the explosion. In his own case, after wearing the pneumataphor for 10 minutes, without much exertion, there was difficulty in breathing and a feeling of distress, and he might say of weakness. In the course of 20 minutes, when travelling down a broken roadway it was almost impossible to do more than take care of himself. In one case, at the end of 20 minutes, respiration was at the rate of 44 per minute, and the pulse was 144; and he would not have been able to pick up another man and carry him any distance. With a pneumataphor and a good electric light, exploration-work could be carried on in a pit that could not be done without it; and in that way the apparatus might be useful in saving property. The experiments at Altofts colliery were not altogether satisfactory, as the atmosphere was not poisonous. A mouse was placed in the gallery, and it was alive after being in the gas for an hour; but the workmen were as much inconvenienced as if they had been in deleterious gases. The experimental gallery presented all the difficulties that they would experience in a pit after an explosion. The workmen, however, were familiar with that gallery, and during part of the experiments the gallery was lighted by electricity, which would not be the case in a pit after an explosion. The different life-saving appliances in use were capable of great improvement: for instance, the mouth-piece was now placed under the control of the wearer. He remembered suffering great distress after using it for 35 minutes, and he had an almost irresistible impulse to pull the mouth-piece out of his mouth and to have a free breathe. The pneumataphor, in its early stage, had only one oxygen-cylinder, and he knew a colliery where a road-way was penetrated for a distance of 350 to 400 feet; the oxygen-cylinder then became exhausted, and the wearer had to return. Fortunately, it was a good road for travelling, and it did not take him long to get out. The apparatus should be provided with two oxygen-cylinders, each capable of lasting 35 minutes. He thought that each cylinder was safe for about ½ hour,

and one could be used when going in, and the other when returning.

Mr. J. T. Stobbs asked whether any attempt had been made to reproduce a bad or dangerous roof in the experimental chamber.

The President replied that broken pieces of timber were hanging from the roof, without incommoding the progress of the workmen; and the place was made as like a roadway where a fall had been caused by an explosion as they could expect. But there was no danger of anything falling from the roof.

Mr. J. T. Stobbs remarked that the Meyer helmet could not be used with safety by anyone who had not had experience with it.

The President observed that it would be foolish for an inexperienced person, when using any of these different appliances, to go into a dangerous place until he had had considerable practice in their use.

Mr. A. M. Henshaw said that he preferred the pneumataphor to the Meyer helmet. The helmet made him feel that he had his head in a bag, while the pneumataphor did not produce such an uncomfortable and dangerous effect.

The President remarked that it was by no means a difficult task to gain the necessary experience in the use of the pneumataphor.

Mr. E. B. Wain thought that it would be difficult to maintain a rescue-station in the North Staffordshire district and place it in such a position that it would be available for all the collieries, as they were spread over so wide an area.

The President thought that North Staffordshire compared favourably with other districts in this respect.

Mr. M. H. Habershon wrote that the building for the proposed colliery rescue-station referred to in his paper was being erected jointly by the Barrow Hematite Steel Company, Messrs. Newton Chambers & Company and the Wharncliffe Silkstone Colliery Company, whose collieries were closely adjoining.

## ARRANGEMENT AND TIGHTENING OF GUIDE-RODS.

Mr. E. B. WAIN remarked that there had been in that district recently several accidents in shafts caused by cages coming into collision at meeting where wire-rod guides were in use. There were various methods of arranging and tightening guide-rods. At some pits, screws were used; in another there were tension-weights at the top of the pit, and the weight was applied to the rod by levers; and in South Wales, strong springs fixed to the headgear were used. He suggested that a committee should be formed to enquire into the subject, which was of considerable importance, in view of the great depths at which the North Staffordshire collieries were now being worked.

After discussion, Messrs. G. Greatbach, A. M. Henshaw, J. T. Stobbs, E. B. Wain and the Secretary, were appointed a committee to report upon the subject.

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## DISCUSSION OF MR. POOLE'S PAPER ON "THE COAL-FIELDS OF NEW BRUNSWICK, CANADA."*

Dr. EDWARD GILPIN (Halifax, Nova Scotia) wrote that the description given by Mr. Poole correctly covered the position and extent of the New Brunswick coal-field. In a report dated in 1881, Mr. Ells, of the Geological Survey of Canada, considered the coal-bearing strata to be equivalents of the Millstone Grit.† The area of the best coal lies immediately north of Grand Lake, covering about 100 square miles, and it is estimated, after deductions for waste ground, to contain 50,000,000 tons. The Geological Survey estimated the coal-contents of the entire coal-field at 150,000,000 tons. The coal varies in thickness over the territory in question from 18 to 36 inches, averaging about 24 inches. The quality of the coal when cleaned, is good, but as shipped it is very dirty. Its composition may be gathered from the following analyses:—

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 40.

† *Geological and Natural History Survey of Canada, Reports 1880-81-82*, section D, page 3.

| | New Brunswick Coals. | | | Cape Breton Coals. |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| Volatile matter ... | 37·30 | 35·25 | 37·10 | 33·44 |
| Fixed carbon ... | 59·35 | 55·80 | 61·10 | 61·87 |
| Ash ... ... | 3·35 | 4·20 | 1·80 | 4·22 |
| Sulphur ... ... | 2·60 | 1·68 | 1·98 | 2·37 |
| Coke ... ... | 62·72 | 60·00 | 62·90 | — |
| Moisture ... ... | — | 4·75 | — | — |

For comparison, he (Dr. Gilpin) also gave the average result of a number of analyses of Cape Breton coals. This coal-field, originally discovered about 200 years ago by the French, near the eastern end of Grand Lake, had since been worked to a very small extent. It is not probable that the immediate future will see a large development in face of the thicker and more cheaply worked seams of Nova Scotia, and the opportunities for sea-transport of outside coals to the principal points of demand which are on tide-water. At some future date, when economic conditions permit, this coal-field will prove a valuable domestic source of fuel to New Brunswick.

# SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

GENERAL MEETING,
HELD AT THE UNIVERSITY, BIRMINGHAM, APRIL 14TH, 1902.

DR. CHARLES LAPWORTH, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentleman was elected:—

MEMBER—

Mr. ALLAN GILMOUR MACLATCHY, General Manager, Transvaal Consolidated Coal-mines, Transvaal, South Africa.

## ROYAL COMMISSION ON COAL-SUPPLIES.

The PRESIDENT (Dr. Charles Lapworth) stated that the Royal Commission, to which Mr. Arthur Sopwith and himself had been appointed, was intended to ascertain the coal-resources of the United Kingdom, at what rate they were being exhausted, how long they might reasonably be expected to last, what was the area of known buried coal-fields, and whether it was probable that others would be discovered in the future. The former Royal Commission worked for five years before making a report. The present Royal Commission had very heavy work before them, and it might be a matter of several years before they would be able to make their report. The colliery-proprietors in the United Kingdom had had sent to them a circular letter, with a complete form, asking them for information as to the extent of their royalties, what was the area of coal on the estate, and what was the rate of exhaustion. These forms were now being gradually filled up and returned to the Secretary of the Royal Commission, and when the information had been carefully tabulated, the first stage of the work would be completed.

Mr. T. J. DAVIES (Vice-President) then took the chair.

Mr. J. H. WHITTAKER read the following paper on "Sparkless Electric Plant for use in Mines and Ironworks":—

# SPARKLESS ELECTRIC PLANT FOR USE IN MINES AND IRONWORKS.

By J. H. WHITTAKER.

*Introduction.*—There are many electric light- and power-plants doing good work in mines for surface-lighting and underground work, but on the whole, electric plants have been adopted somewhat slowly, and proprietors and colliery-engineers avoid their use, the writer fears, because they know little of electrical science, and are somewhat nervous about a bogey which ignites gases in an almost unseen manner.

Electric light has been used now for many years, for lighting pit-bottoms, underground engine-rooms, and junctions on the roads near the pit-bottom; but it has been seldom taken along the roads, as there are difficulties in carrying the electric light into the workings, due to slips or falls of roof.

The generators, being fixed in the engine-house at the surface, are generally well cared for; and little need be said on the question of carrying cables down the shaft. The wires may be hung directly from end to end, bare, or double or triple-braided only, from an insulator at the top of the shaft, a piece of well-insulated cable being connected a few feet from the bottom; or they may be thoroughly insulated single, twin, or concentric cables, and passed through tubes, or laid in wooden troughs and filled in with bitumen, or carried down the shaft on insulators. Each method of conveying the power from the generator to the pit-bottom, possesses certain advantages, and the decision as to the method to be adopted generally depends on the nature of the shaft, its dryness or otherwise, and the chemical constituents found in the waters thereof.

*Continuous-current Plant.*—Continuous-current motors are now supplied and built specially for colliery or ironworks use, strong and durable. In fact, it is common to think more, at any

rate among engineers, of the lasting powers of such machinery than either of appearance or of 1 to 2 per cent. of efficiency; and ease of winding or of repairing the windings, and depth of wear allowed in the commutator, are considered most important items.

Three classes of motors are used in collieries:—Series-motors for incline-hauling and hoisting, and in some cases for endless haulage; and also for working coal-cutting machinery. They work efficiently, and generally withstand considerable overloading: but should they lose their load and be left unattended their speed will rise to several thousands of revolutions per minute, and probably the armature and its windings will fly to pieces owing to the enormous centrifugal stresses created.

In the shunt-motor, the current is passed by separate windings round the field-magnets. This motor is not so good a starter, but it runs at a regular speed after having attained its full speed, and will generally carry 20 per cent. of overload for an hour without serious trouble. A source of danger and liability to break down lies in the method of connecting the main and starting-switches, and if it is possible to break the shunt-circuit, when there is nothing to receive the back electromotive force, a tremendous arcing flash will result, burning the switches and very often firing the shunt-coil.

The compound motor, a combination of the two, on the whole appears to be most suitable for general use in collieries, as it can be connected so as to become an excellent starter and to work at a very regular speed, with a variation not exceeding 5 per cent. between no load and full load.

In all continuous-current motors, the great source of trouble lies in the commutator and armature: the field-magnets being stationary, if the motor be erected in a fairly dry position, there need be no trouble whatever with them. Commutators are constructed specially for the purpose of making and breaking the electric connection, consequently it is almost impossible to make motors that will work absolutely without sparking. Then again the windings of an armature, whether it be for a shunt, series, or compound-wound motor, must carry the full voltage and practically the full current necessary to ensure that the motor shall yield the power required, the strain on the insulation being

greatest at the weakest places, where the windings are crossed and re-crossed many times in the endeavour to obtain the maximum result from a given size of material.

Trouble is generally to be found also without much searching at starting-switches, as they are almost always much too small for the work that they are called upon to do. Starting-switches can certainly be made large, and can stand rough usage, but the generality of switches in use, being of American type, appear to have been made to sell rather than to use. They will generally start a motor, provided you are sufficiently smart, and risk burning your commutator and brushes by switching-on the current in a rapid manner.

It is scarcely advisable to fix a continuous-current motor of any kind, in a fiery mine, although the writer does not think that there is a case on record of gas having been fired by the spark from the motor-brush. It is of course possible to obtain motors, which are absolutely enclosed and perfectly gas-tight, at a greater expense in first cost, and a continued expense during the life of the motor, as the motor will be generally inefficient and very large for the work that it is capable of doing, and consequently very costly. And, as a rule, a machine that works in a gas-tight chamber is generally allowed to work without being looked at, until it goes wrong.

Colliery-managers seem to be generally of opinion that an open type of machine should be used, or an open protected machine should be built in such a way that the iron case protects the coils but allows a fair amount of room for inspection and cleaning; and if continuous-current motors are not well cleaned, sparking of commutators, burnt brushes and burn-outs of the armatures will be matters of very frequent occurrence.

*Polyphase Plant.*—Engineers usually desire that electric-power plant should be devised to run entirely without sparking or burning, without wear of brushes and commutators, and that it should be possible to overload the machinery for a considerable time without risk of failure. Three-phase electric-current machinery meets these requirements of engineers: such machinery has been designed, and used for almost any purpose that may be required, and the work has in most cases been performed better than by continuous-current plant. Three wires

must be used with three-phase machinery, and lest this should be considered a disadvantage, the writer may mention that the diminished sectional area of the wires for a given power effects a considerable saving in the weight of copper; and as it is possible to use higher voltages than can be used for continuous-current motors, the saving in the weight of copper may be 50 per cent. or more.

A three-phase alternator may be considered as an ideal electric generator. Various forms are constructed, and the best, from a mechanical point of view, consists of a steel structure having windings mounted on the stationary portion of the machine, the rotating part being a solid steel casting. The generator has no commutator, slip-rings, brushes, nor collectors of any kind, the ends of the windings being carried to terminals on the terminal-block of the machine. Such a generator will carry 100 per cent. of overload for 1 or 2 hours, if necessary; it will not spark, nor is it necessary that it shall be watched with a view to moving the brushes during the varying loads, as there are no brushes to move or spark. It is necessary to have a small continuous-current machine running in each engine-house, driven either by belt or directly connected to the alternator, this machine being used for energizing the field-magnets of the alternator.

The switchboards for three-phase machinery are simple, one ammeter and one voltmeter being placed on one of the three mains leading from the machine, as the current will be exactly the same in all mains.

There is no difficulty with three-phase cables, as it is just as easy to run three bare mains down the shaft as it is to run two, especially considering that they are lighter in weight, or three separate rubber-cables or three core-cables made up as one, or a triple concentric cable may be used: and at the pit-bottom and on the roads, junction-boxes having three-ways may be connected at intervals, and three branch-wires taken therefrom to the various motors.

A motor-switchboard consists of a slab of slate, preferably attached to an iron frame, fitted with a three-pole switch, a voltmeter (an ammeter may be in circuit if desired) and main fuses.

A three-phase motor consists of two parts, a stator which generally compares with what is usually called the field-magnet

system of a continuous-current machine. This, which is the stationary part of the machine, is the only part that is wound in connection with the line-wires, so that the voltage in the line may be anything from 100 volts to 5,000, and many motors are being run and have been running now for 6 or 8 years with 5,000 volts between any pair of terminals. The windings can be thoroughly insulated, and seeing that they are never moved, there is very little difficulty in arranging them so that they will stand practically any voltage, and if well insulated and water-proofed, these windings should stand without leakage in damp and wet places. There are many motors running at high voltages, exposed to the open air and fogs.

The second part of the machine, or rotor, corresponds to the armature of a continuous-current motor. In small sizes, ½ horsepower or thereabouts, they are generally made of a solid block of steel and have no windings, and these make no contact with anything except their bearings. From 1 to 10 horsepower, the rotors are generally built of laminations, having copper-rods or bars laid in slots or holes as near as possible to the periphery. These rods may or may not be insulated, only 1 or 2 per cent. of increased efficiency being gained by insulation, and should the insulation become worn or rubbed away, sparking or burning cannot possibly occur, the motor will still do its work. Without minute examination one would never know that the insulation had become removed, as these bars are already of set purpose short-circuited at certain parts of the iron portion of the rotor. These rods are generally passed through holes, which are stamped in the sheet-iron laminations, and there is absolutely no necessity for binding-wires, string, or insulation. The current that passes along the copper rods, fixed in the rotor, is an induced current, the pressure of which does not exceed about 5 to 10 volts. Therefore, as we cannot obtain efficiency in transmitting electric power over long distances, without high voltages, and as armatures will not stand high voltages without risk of injury, we have dispensed entirely with the passage of current to the armature or rotating part, and confined the high line-voltage to the stationary windings which can be well insulated and where there is no wear.

The only limit of output is the heating of the stator on overloading, but most three-phase motors will withstand 50 to 100 per cent of overloading. Wear-and-tear is reduced to the friction of

the bearings, and as these machines can be made self-lubricating, so long as there is oil in the bearings, the machine requires no attention. The starting torque is about 2½ times full-load torque, and the machine will, therefore, start against a dead-load.

One type of motor is equally suitable for hauling, pumping, rock- or coal-drilling, or general shafting work, and up to 10 horsepower, they can be switched directly into circuit by means of a three-pole switch, no resistance being used, and there is no risk of arcing, or piercing or firing the insulation, on making or breaking contact.

The speed of these motors depends upon the speed of the generator or the speed of the rotating field produced in accordance with the speed and number of poles on the generator. This may possibly be considered a disadvantage, as the speed cannot be varied except by altering the connections and number of poles of the motor, or varying the speed of the generator; but compared with the fact that the motor is bound to run at the given number of revolutions under all conditions, lightly loaded or fully loaded; that it cannot run away if connected to a pump, should the pump miss the water; and that haulage-motors cannot race with light loads, the importance of varying the speed is very slight, as this can be effected by the use of belt-pulleys or gearing.

Variable-speed motors can be made on the three-phase principle by an expedient which is essential when the power exceeds 10 horsepower. In these cases, in order to obtain speed-variation and for the starting of motors exceeding 10 horsepower, the rotor bars or windings are connected by wires to slip-rings on the end of the shaft, and resistances connected through a starting-switch, by means of which the largest size motor may be started without taking more than the usual full-load current; but it should be noted that, as soon as full speed is obtained with any size three-phase motor, these slip-rings are short-circuited and the resistances entirely disconnected, until it is necessary to use them for starting again, or varying the speed.

It should be remembered that there are no commutators, or breaks in the slip-rings or sliding-contacts of these motors, and whether they be of 20 or 1,000 horsepower they will run entirely without sparking, and it will be impossible to make them spark by any means short of forcibly breaking the connections or tearing the wires out of the terminals.

*Pumping.*—Three-phase motors are ideal machines for driving pumping plant, as they are started by closing a simple switch, start easily, run up to speed, and maintain a perfectly steady speed under all variations of the supply of water.

*Coal-cutting.*—It is usual to use series-motors where continuous current is employed for this work, a heavy starting resistance being used; should the cutter be jammed as soon as the current is switched on, it will cause violent sparking at the commutator, and unless immediately switched out, the probabilities are (unless the fuses blow) that the coils of the armature will be burnt. If the fuses are made heavy enough to stand the exigencies of this severe work, there is the great risk mentioned of burning the coils; and if on the other hand they are moderately light, they will be continually blowing, and will be a cause of great delay in working.

Three-phase currents offer considerable advantages for driving coal-cutting machinery; wheel-cutters have been fitted with two motors of 10 horsepower geared to the cutter through reducing gear, and the full pressure, generally about 600 volts, is switched straight on to the machine. If the cutter be jammed, while the motor will not start away at once, the fuses do not blow, and the current taken is only about double that of full load, but the motor and gearing can be started by reversing and starting again. It is usually found that by this means the wheel will gradually be freed, it being usual to allow a certain amount of backlash in the gearing to allow of the adoption of this method of reversing and starting the machine. When using three-phase motors in this way, it will of course be necessary to make the three-pole switches very heavy in their metal parts, and as the operation of reversing is simply the pulling-over of a lever, it has been found that this method of operating coal-cutters has proved so satisfactory that in some cases a special rotary converter has been put in to convert the current, which has already been carried down the shaft as continuous current, into three-phase current for use with these motors.

*General Engineering and Shop-work.*—These machines can be fixed in any position on the floor, wall, or ceiling; they can be left entirely unattended for 6 to 12 months, if the bearings are fitted with suitable lubricators, with ample oil-wells; and there is

absolutely no reason whatever for touching them, except when placed in dirty positions. Although an electrical engineer should be the last to encourage dirty machines or neglect of inspection—the prime causes of more than half the breakdowns of electric machinery—yet with confidence, the writer can affirm that except for an occasional clean-out with a cloth, it is absolutely unnecessary to touch a three-phase motor. The running life, seeing that only their bearing-surfaces are subject to any friction, will be more than double that of continuous-current motors; the efficiency is as high as that of the best continuous-current motor in the best of condition; and seeing that it is so difficult to keep continuous-current motors in good condition, as a rule three-phase motors will yield a higher efficiency.

*Transformers.*—The system of raising or dropping the voltage with an alternating current is very simple and efficient. If power is required at a distance of 1 mile from the generator, it would be desirable to generate the current at a high pressure, say, 5,000 volts; carry it by insulated cables; and then transform to about 1,000 or 600 volts, or lower if preferred. Such a transformer would be a stationary piece of apparatus, enclosed in an iron case with six terminals. There is no moving parts whatever, and the current is carried into three terminals at the high voltage, and issues at the other three at the low voltage. The transformation of voltage will usually entail a loss of only 3 or 4 per cent., and considering the reduced size of the leads for 1 mile or more of wire, this loss can first be gained and the expenditure of a very considerable amount of capital avoided.

*Lighting.*—Three-phase electric currents are not so advantageous for electric lighting as continuous currents, but where the working of motors is the most important item and a separate plant for lighting would increase the cost, it is certainly possible to arrange for satisfactory lighting. Lamps can be connected between any two wires, but care should be taken that as nearly as possible the same number of lamps are connected between each pair of wires; or a common or neutral wire, that is a fourth wire may be run, and all lamps connected between this fourth wire and the other three, but the number of lamps should also be balanced between this fourth wire and the other three as in the preceding method.

Arc-lighting is not desirable for colliery use, although arc-lamps are supplied to burn satisfactorily with alternating current.

Some of the members may think that the writer has stated all the advantages attending the use of polyphase machinery and very little of the disadvantages; but he has not striven to hide the disadvantages. He has personally seen a few thousands of three-phase motors driving almost all classes of machinery, and in this paper he has simply aimed at introducing the subject to the members.

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Mr. Isaac Meachem, jun., said that, a short time ago, he had erected an electrical plant. When consulted, the electrical engineers recommended the polyphase-current system for pumping only, but when he decided to drive haulage machinery and to light the mine from the same motor they advised a compound-wound motor, on the continuous-current system and the result had justified its adoption, and now he was advised to apply electric power to rock-drilling. And he had found the continuous-current system to answer admirably in each of the three electric mining-plants under his charge.

Mr. T. H. Bailey stated that, as the result of the arbitration between the District and Metropolitan Railways, Mr. Alfred Littleton, K.C., M.P., the umpire, had decided, after hearing expert evidence, that the continuous-current system was the best. He (Mr. Bailey) thought that, in the face of such an opinion, mining-engineers should proceed with caution before adopting a polyphase-system.

Mr. Alexander Smith (Secretary) stated that constructional electrical engineers were very undecided as to which of the two systems was the best.

The Chairman (Mr. T. J. Davies) proposed a hearty vote of thanks to Mr. Whittaker for his interesting paper.

Mr. I. Meachem, jun., seconded the resolution, which was unanimously approved.

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# MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE QUEEN'S HOTEL, LEEDS,
APRIL 8TH, 1902.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

Mr. WILLIAM SCOTT read the following paper on "The Craig Coal-Washer":—

## THE CRAIG COAL-WASHER.

BY WILLIAM SCOTT.

The increasing necessity of dealing with the more unsaleable portion of the output of collieries, and the problem of satisfactorily extracting and washing the products of dirty and inferior seams of coal, has led to the introduction of the Craig coal-washer. The more valuable coking-seams are now being rapidly exhausted, and another and important question has arisen, namely, the discontinued use of the riddle, in many of the collieries in the area of the Miners' Federation. Consequently, a larger amount of smudge is now sent out than formerly; and it is, of course, accompanied by admixed foreign matter, which, the collier knows well enough, cannot be detected easily at the screens.

There are already numerous forms of coal-washing machines: Some are more or less effective, but their cost prohibits their use at collieries with a limited output; and others, although comparatively cheap to erect, are most expensive to work, maintain and repair. With the first-named class, the Craig coal-washer does not pretend to compete, inasmuch as it is primarily intended to deal with smudge or, at best, with the smaller sizes of coal, except in so far as these larger types themselves deal with a similar product. With the second class of washer, however, it

enters into direct competition; and, as the limited opportunities for trials prove, the results are of a most encouraging nature and show that its introduction is already justified.

The Craig machine was originally intended for gold-washing; and, as the members will readily understand, the process is reversed, as the dirt in this case is dealt with in the same manner as the valuable metal, while the coal or lighter product goes where the dirt was dealt with in the other case.

Before actually washing the coal, as it comes from the pit or other source, it is thoroughly mixed with water, in a special mixer or scrubber, A (Figs. 1 and 2, Plate XI.). This mixer is an upright cylinder, usually about 6 feet high by 4½ feet in diameter, in which an arrangement of stirring-arms, revolving at a suitable speed, thoroughly intermix the coal, dirt and water. The size of the mixer depends on the amount of material to be treated and the number of washing-tables which it is intended to supply; and, as a rule, one of the size given is capable of serving from one to eight tables. From the mixer, the wetted material is allowed to gravitate through regulated openings, along spouts, to the tables or washers.

The washing-table or vanner (Figs. 3, 4 and 5, Plate XI.) is a Y-shaped structure, having a length and breadth of about 12 feet across the extremes. The mixed coal and water is delivered upon the table, at B, where it has an inclination of 1 in 6, but this can be altered to suit varying conditions. It will be apparent that the flow of water and the supply of coal are also capable of variation to suit the particular needs of the stuff treated. The table is mounted on a wheeled bogie, C, on inclined rails, D, and has a reciprocating motion, obtained partly from a cam, E, 16 inches in extreme diameter, driven from an overhead shaft, F, running about 30 revolutions per minute, by a chain, G, on sprocket-wheels, H, 18 inches in diameter. On the release of the cam, E, the return stroke is obtained partly by the inclined position of the bogie on its rails and partly by strong springs, I, which pull the moving table with a jerk against a buffer, J. The table is driven at a speed of about 60 strokes per minute, depending upon the nature of the material to be washed. The length of the stroke is 5 inches.

Having arrived at B, the wetted coal and muck is carried

forward by the flow of water and the rocking-motion of the bogie, to the flatter portion of the table, K, where the actual separation of coal and foreign matter takes place. This part of the table has a very slight forward inclination, capable of variation to any required degree by means of set-screws, L and M, on the bogie-frame. From K, the coal, being lightest, is carried forward and finally ejected from the table by the spouts, N, N. In the course of separation, the impurities are gradually jerked backwards, and pass from the machine by the horn-spouts, O, O, where they are delivered into wagons or other methods for removal to the spoil-heap. Should any coal actually pass backwards by becoming embedded in the dirt, this is effectually prevented by a sprinkling of pure water from overhead perforated spouts, P, P, the supply being capable of nice adjustment; and thus any remaining trace of good coal is then carried forward along with the rest. The guiding principle in all washing operations has hitherto been one of gravity only, but a separate and distinctly different movement is introduced in this machine, which, however, takes full advantage of the gravitation-process.

In conjunction with this washer, a novel form of storage has been devised, in the form of a circular wooden structure (Figs. 1 and 2, Plate XI.). The vertical joints are properly slivered; and, as both coal and water have to be accommodated, a sufficient number of these circular tanks must be provided. Quick drainage is ensured by a square wooden pipe, which has one of its four sides formed of fine copper-gauze, being placed vertically, at a point farthest from where the coal is delivered into the hopper, so that the stock of coal, constantly being added, forms an additional filtering-bed and prevents the finest portions of coal from passing away as settlings. This system has been so successful that the water leaves the hopper clean enough to be at once used at the washer.

An experimental plant on this system was erected at Coanwood colliery in Northumberland. Owing to the exhaustion of the royalty this machine is not now working, but up to the time of the stoppage, it washed the coal efficiently and to the entire satisfaction of the owners of the colliery. The coal was worked from the neighbourhood of the great or 90 fathoms dyke and amid very

faulty ground. The excellent results obtained at Coanw colliery with this machine are clearly proved by the follow analyses:—

| | Before Washing. Per cent. | After Wash Per cent. |
|---|---|---|
| Moisture ... ... ... ... ... ... | 2·07 | 2·19 |
| Ash ... ... ... ... ... ... ... | 11·51 | 4·80 |
| Volatile combustible matter ... ... ... | 29·63 | 32·61 |
| Fixed carbon ... ... ... ... ... | 56·79 | 60·40 |
| | 100·00 | 100·00 |
| Sulphur ... ... ... ... ... | 1·96 | 1·65 |
| Coke ... ... ... ... ... ... | 68·30 | 65·20 |

In the above analyses, the sulphur is included partly in the and partly in the volatile combustible matter.

Another quality of smudge, dealt with by this machine, c tained 25 per cent. of dirt, which was reduced by washing t per cent.

Two plants are at work in Yorkshire, with which simi results are obtained, and a third and very complete plant is course of erection.

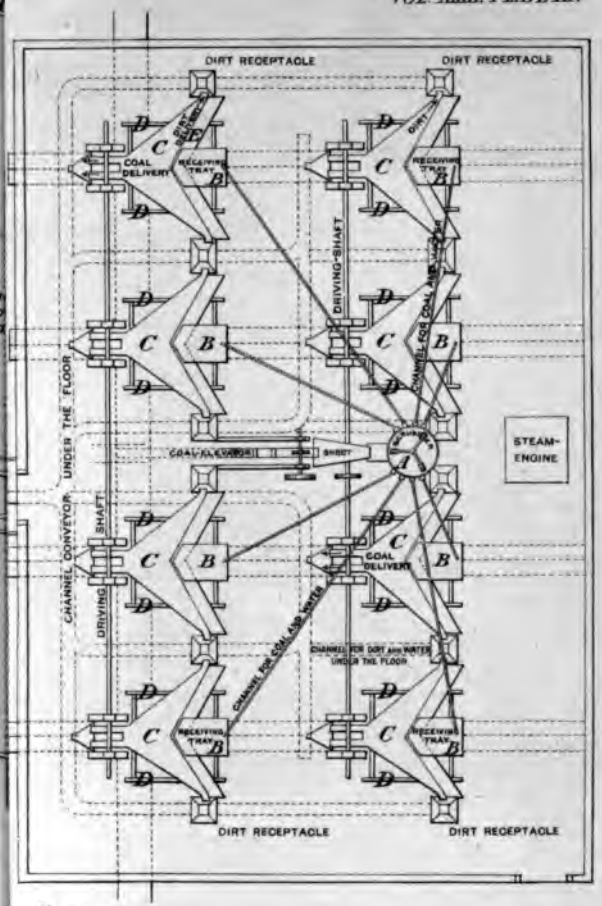
Each table is capable of treating from 40 to 70 tons of mate per day of 10 hours, depending upon the composition of t coal to be washed. If storage be available, there is no limit the number of the tables, and the washery can be extended to a required extent, or any one table may be stopped without impa ing or affecting the usefulness of the others. This is a great ga because usually the whole washery has to stand while the mo trifling repair is being executed.

The power necessary to drive the tables is very small. Coanwood colliery, an engine with a single cylinder, 6 inches diameter, was driving three tables, but this did not include t driving of the mixer and the disintegrator, or the conveying material to the washer, a factor which will obtain whatev description of machine may be used. The Coanwood plant erected on an old spoil-heap, shewing that the foundations are n of a costly character.

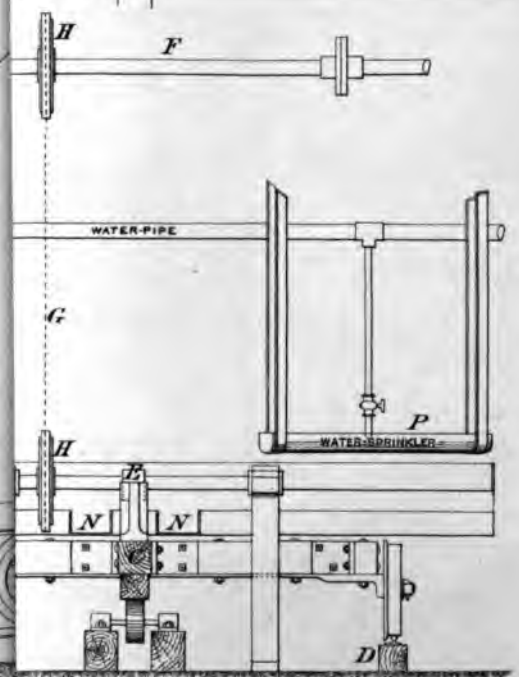
This machine is not intended to compete with large washeri as regards the class of coal treated, but it will deal with an quantity of coal within its sizing capacity and that in a mann

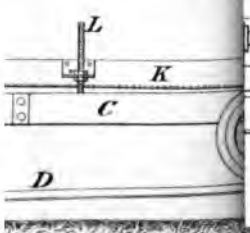
*Paper on "The*

*Vol. XXIII. Plate XI.*




*16 Feet to 1 Inch.*




ELEVATION.

5.—FRONT ELEVATION.

Comp.ʸ L.ᵗᵈ Newcastle on Tyne

*Vol. XVI. Plate XII.*

which these larger machines can never hope to do. It will only wash coal up to 1½ inches in diameter, and any larger size must be crushed, although trials are being made for the washing of larger sizes. Regularity of working is desirable, if the best results are to be obtained from the Craig washer: and it may be specially mentioned that up to a certain size (1½ inches), there is no need for sizing, as it is a peculiarity of this washer that it works better so, the finer stuff forming a bed on which the larger is gradually shifted forward.

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Mr. H. B. NASH, in moving a vote of thanks to Mr. Scott, remarked that the members could have no difficulty in following the results, and the reason for these results being obtained.

Mr. W. H. PICKERING, in seconding the motion, said that the Craig coal-washer appeared to be a most excellent one.

The motion was cordially approved.

Mr. W. SCOTT explained by a model the working of the washer. The coal was thoroughly wetted before being placed in the washer, and that operation he considered to be essential for efficient washing. In the washing-plant at Coanwood colliery the water is poured through a pipe, and the coal lifted from the wagons into the scrubbing cylinder, which is kept as nearly full as possible.

Mr. T. W. H. MITCHELL asked why the coal did not go away with the dirt down the horned spouts.

Mr. W. SCOTT: Because the water forces it forward.

Mr. J. E. CHAMBERS asked how the capacity of the washer was increased.

Mr. W. SCOTT: By placing another washer at the side. One mixer was capable of supplying coals to several washing-tables. The plant erected at Coanwood colliery, consisting of a mixer and three tables, was capable of washing 250 tons per day of 10 hours. The cost was about £300; or say £100 for each table, exclusive of the cost of erection.

The PRESIDENT (Mr. J. Gerrard) asked whether the apparatus was efficient.

Mr. W. SCOTT considered that the Craig washer was very efficient.

The PRESIDENT said that it had now become essential that coal should be efficiently cleaned. The washing and treating of coal would become of greater importance during the next few years.

Mr. ISAAC HODGES remarked that the Craig washer was an adaptation of an ore-dressing plant. He thought that Mr. Scott had not laid sufficient emphasis upon the fact that the whole secret of the efficiency of the washer lay in the gradient of the table; and he understood that the most suitable gradient generally was 1 in 6. The force of the water carried over the lighter material, and the heavier material, very often dirt, was thrown back by the excentric movement of the table. He had no doubt that it was necessary that the building should be of considerable strength, to withstand the constant shock of the table. Coal-owners, who had erected coal-washing plant had found that costly appliances were required to retain the "silt." The only effective means that he knew was that of filtering the dirty water through slack-coal. He had seen, about three years ago, at the Thornhill collieries, an experimental tank, with a content of about 2,000 cubic feet, with a perforated bottom, made of malt-kiln tiles, containing 800 tapered holes to the square foot. Excellent results were also obtained by the washing-plant at the Whitwood collieries, in which the water was filtered in tanks containing slack-coal, the issuing water being perfectly clear.

Mr. PERCY C. GREAVES stated that he had a Craig washer which was not working so efficiently as he should like, but Mr. Craig told him that it was not fixed so perfectly as it should be. He was pleased with the easy way of dealing with the dirt, which came away with a minimum volume of water. He sometimes found that lumps of coal, measuring about 1 inch by 1½ inches, had a tendency to travel with dirt, but small coal readily went through.

Mr. WALTER HARGREAVES considered that the most important point was the claim that the Craig machine would efficiently wash smudge or duff. Any washer would wash nuts, and if the Craig machine would wash smudge, it was a most valuable invention. Did Mr. Hodges state that he had abolished settling-tanks by putting the water and slurry from the washer into the storage-hoppers?

Mr. P. C. GREAVES said that he did not use proper settling-tanks, the waste-water being run over an old spoil-heap, and allowed to drain away.

Mr. I. HODGES said that settling-tanks were used for the dirt from all washers. The dirt was charged into hoppers, and settling-tanks were used to catch the water draining from the dirt. The only water taken from the washer at Whitwood collieries was the water carried away with the washed slack, and that was the only water that had to be replaced.

Mr. W. SCOTT said there could be no doubt that the tank formerly worked at Thornhill collieries was a supremely excellent one, but, unfortunately, its use had been abandoned. The settling-tanks of the Craig washer were an improvement, in his opinion. The water issuing from the coal-storage tanks at Coanwood colliery was pure, and to use the words of a mining-engineer who had inspected the plant, it was "fit to drink." The principle of the drainage, as Mr. Hodges had said, was that the coal filtered the water, and the continual addition of coal formed an additional filter-bed. The water from the dirt ran into a beck.

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Mr. EDWARD BROWN read the following paper "An Apparatus for lighting Miners' Safety or other Enclosed Lamps by Electric Current":—

# AN APPARATUS FOR LIGHTING MINERS' SAFETY OR OTHER ENCLOSED LAMPS BY ELECTRIC CURRENT.

By EDWARD BROWN.

Where large numbers of safety-lamps are required to be lighted and locked, before the arrival of the workmen, it is necessary to commence lighting the lamps, probably, 2 hours before the arrival of the men, whereby say 1½ hours of the best part of a lamp's shift is wasted in the cabin at the pit-top. It will generally be admitted that, if some inexpensive and reliable method were introduced, whereby the lamps could be all locked, before any of them were lighted, the lighting need not be commenced till within, say, ½ hour before the arrival of the men. The lamps would consequently be capable of giving a much better light, in the latter hours of the shift, and at the same time a considerable amount of oil would be saved.

Hitherto the methods of lighting miners' safety or other enclosed lamps, by an electric current, have required one or more wires to pass through the oil-vessel forming the bottom of the lamp, and insulated therefrom, thus requiring considerable alteration to the bottom or oil-vessel, and making the insulation of the wire or wires difficult and uncertain.

The present invention is designed to overcome these objections, and consists of a metallic conductor, AD, fixed in the glass, B, surrounding the wick-tube, C, of the lamp. The metallic conductor, AD, projects inwards towards the wick-tube, C, and slightly above but not touching it, the outer end of the conductor, AD, being shaped so as to form a contact at D (Fig. 1).

The lighting-stand is formed of wood or other non-conducting material, and a metallic plate, E, to which one high-tension terminal, F, of the induction-coil is connected by a wire, G, and the other high-tension terminal, H, is connected by the wire, J, to a sliding-conductor, I. This conductor, I, presses against a

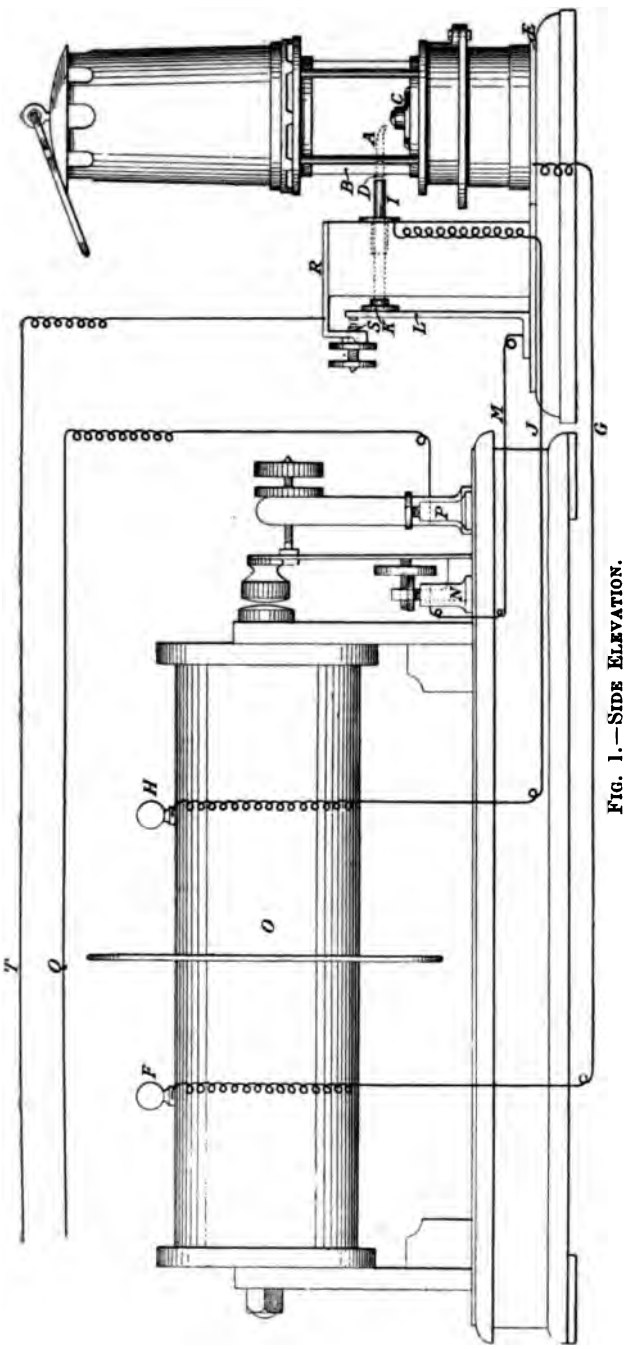


FIG. 1.—SIDE ELEVATION.

piece of insulating-material, K, attached to a spring, L; and the spring, L, is attached to a wire, M, which is connected to one terminal, N, of the primary circuit of the induction-coil, O. The second terminal, P, of the primary circuit is connected to the storage-battery or other source of electricity by a wire, Q.

On the top of the lighting-stand is fixed a plate, R, carrying an adjusting screw, S, and the plate, R, is connected to the storage-battery or other source of electricity by a wire, T. The action is as follows:—The lamp to be lighted (which has previously been cleaned, trimmed and locked) being placed on the lighting-stand, the bottom resting on the metallic plate, E, and the contact, D, touching the sliding-conductor, I, a slight push of the lamp closes the primary circuit, between S and L; the induced current, through G and J, forms an arc between the point of the metallic conductor, AD, and the wick-tube, C, thus lighting the wick of the lamp; and on withdrawing the lamp, the primary circuit between S and L is automatically broken. By this apparatus an ordinary safety or enclosed lamp of any type may be electrically lighted without requiring an insulated conductor to be passed through the lamp-bottom; and the invention can be applied to existing safety-lamps, without necessitating any structural alterations in the lamp, beyond the insertion of a conductor, AD, in the glass surrounding the flame.

This apparatus is intended to be taken into the mine, to any convenient lamp-station, and is locked, so that only the properly appointed person can relight any lamp, which may have been accidentally extinguished.

The lamps, in the lamp-cabin at bank, can be lighted as they stand, on a wire running along the shelves. This wire is connected to one of the high-tension terminals of the induction-coil, and a flexible cable, with a push formed in the handle, is carried to any lamp required to be lighted, the end of the push being connected by a wire to the other high-tension terminal on the induction-coil. When the handle is pressed against the metallic conductor fixed in the lamp-glass, it closes the primary circuit, and the induction-spark lights the lamp-wick instantly, and in a similar manner to the fixed stand: in one case, the lamp being taken to the push, and in the other the push being taken to the lamp.

Mr. JOHN NEVIN, in proposing a vote of thanks to Mr. Brown, said that he had seen several methods of lighting lamps by electricity, but that shown was the best which he had yet seen.

Mr. ROUTLEDGE seconded the resolution, which was cordially approved.

Mr. W. H. PICKERING asked how the metallic conductor was fixed in the glass, and whether there was a good joint and no space between the glass and the conductor.

Mr. H. B. NASH asked whether in cleaning the glass the conductor might not be loosened, and whether the glasses were cast with a hole or the holes were drilled afterwards.

The PRESIDENT (Mr. John Gerrard) remarked that Mr. Brown dealt with one most important point, and that was the prevention of any lamp from being relit, which ought not to be relit. To his mind, that was one of the most important points in connection with the relighting of lamps underground: because, with some electrical arrangements, it had been possible for a workman to relight an extinguished safety-lamp, fitted with an arrangement for electric lighting, from the signal-wires. In fixing the apparatus underground, it should be placed so that emissions of small sparks would not be dangerous. Engineers were learning many startling lessons in connection with the use of electricity, though he would not say one word against the development of its use in mining, because he was satisfied that there was an ample field for its application. It, however, should be recognized that absolute safety was essential, and that everything should be done to secure the most perfect efficiency. A most disastrous accident had occurred at Ashton Moss colliery with loss of life, through the fusing of an electric cable, and all elements of danger must be carefully avoided.

Mr. T. W. H. MITCHELL did not approve of the arrangement described by Mr. Brown, as it would be easier for the boys to relight their lamps at a single wire than in the ordinary way of lighting them by means of the button at the bottom. There was more room between the conductor and the bottom of the lamp, than there was in a lamp fitted with buttons at the bottom.

Mr. EDWARD BROWN, replying to the discussion, stated that the conductors were rivetted into the glass, but they were now luted with red-lead, before being rivetted, as an extra precaution. A boy was employed to rivet them, and he did not think that the breakages exceeded 5 in 1,000 glasses. At first, the holes were drilled at the colliery, but now the glasses are purchased with drilled holes. The lamps had been in use for about 15 months. Gasolene was used in all their lamps, and less time was required to light them than if oil were used.

Mr. H. B. NASH asked whether the copper-conductor became expanded by heat and cracked the glass.

Mr. E. BROWN replied that he did not think that there had been 3 cracked glasses, due to expansion, since the lamps were introduced.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## EXCURSION MEETING OF ASSOCIATES AND STUDENTS.

HELD AT WOODHORN COLLIERY, FEBRUARY 20TH, 1902.

MR. T. V. SIMPSON IN THE CHAIR.

## WOODHORN COLLIERY.

Woodhorn colliery, one of the Ashington group of collieries, lies about 1½ miles east of Ashington, and between 4 and 5 miles north of the port of Blyth. There are, at present, two shafts, both sunk to the Plessy coal-seam, at a depth of 864 feet.

*Downcast Shaft.*—The downcast-shaft is 13 feet in diameter, and is used exclusively for drawing coals from the Yard seam at a depth of 573 feet.

The winding-engine, fitted with Cornish double-beat drop-valves and trip-gear, has two cylinders, each 30 inches in diameter by 6 feet stroke, and the drum is 16 feet in diameter. Steam is supplied at a pressure of 80 pounds per square inch. There are two double-decked cages, each deck taking 2 tubs. The tare of the tubs is about 5 cwts. and the average weight of coal per tub about 9 cwts. Steel rail-guides, weighing 15 pounds per foot, are fixed to the shaft-buntons by means of cast-steel sleepers.

The screening-plant and heapstead comprize two vibrating screens for best coal; two cleaning-belts, 60 feet long by 4½ feet wide, running parallel to each other, and a stone-belt is placed between them.

After being weighed, the full tubs pass into Wood-and-Burnett revolving side-tipplers, placed immediately over the best-coal screens. The empty tubs, from both tipplers, gravitate to a point, where they are raised by means of a creeper until they are high enough to run to the back of the shaft. Directly under the

best-coal screens a cross belt is placed for elevating small coal to another vibrating-screen, where this class of coal is further divided into nuts and peas. At the delivery-end of the best-coal belts, there are also further vibrating screens, which can be used for making double nuts, if necessary; and when not required for this purpose, by means of dead-plates they form the spouts for easy delivery of the best coals into the trucks. Beneath the double-nuts screens is another cross-belt for conveying the nuts to trucks on an adjacent line of rails.

The whole of the screening-plant is driven by shafting and belts by an horizontal engine, with one cylinder 13½ inches in diameter by 24 inches stroke, running at 88 revolutions per minute.

*Upcast Shaft.*—The upcast-shaft, 15 feet in diameter, is fitted as a winding-shaft in a similar manner to the downcast-shaft, and is used for raising coals from the Low Main seam at a depth of 780 feet. The banking arrangements at the surface are described in Mr. C. Liddell's paper. The screening-plant is an exact duplicate of the plant already described.

The winding-engine fitted with Cornish double-beat drop-valves and trip-gear, has two cylinders, 28 inches in diameter by 6 feet stroke, and the drum is 16 feet in diameter. Steam is supplied at a pressure of 100 pounds per square inch.

A jack-engine, placed immediately between the two shafts, has two cylinders, 16 inches in diameter by 26 inches stroke, and the drum, 10 feet in diameter, is geared 3 to 1 on the second-motion shaft.

*Pumping-plant.*—A double-acting duplex condensing pumping-engine is temporarily fixed in the Main seam and forces the water to bank from a depth of 500 feet. It has two steam-cylinders, 20 inches in diameter by 2 feet stroke, working two rams, 9 inches in diameter. Should one side of this engine need repairs, the other side may be worked independently, and so maintain a partial delivery. It is capable of delivering 33,000 gallons per hour.

A Cornish direct-acting steam-pump, with cylinders 8 inches in diameter by 12 inches stroke, fitted with a suction-condenser, deals with the feeders lying below the Main seam.

The permanent pumping-plant, in course of erection, will be worked by electric motors. The main generator is of the six-pole continuous-current compound type, developing 300 ampères at 500 volts when running at 500 revolutions per minute. The compound engine, driving the generator, has a high-pressure cylinder, 15¾ inches in diameter, and a low-pressure, 25 inches in diameter, with a stroke of 33 inches, and the flywheel, 14 feet in diameter, is grooved for 10 ropes, 1½ inches in diameter. The main cables are carried down the downcast-shaft to the Yard seam, where the main pumps are fixed.

The main pumps comprize: A three-throw horizontal pump with rams, 10 inches in diameter by 15 inches stroke; and when running at 33 revolutions per minute, it is capable of delivering 400 gallons per minute against a head of 576 feet. This pump is driven by a shunt-wound, constant-speed continuous-current motor of 100 horsepower at 470 volts when running at 550 revolutions per minute.

Another three-throw horizontal pump, with rams 7 inches in diameter and 9 inches stroke, fixed in the Low Main seam, when running at 42 revolutions per minute, is capable of pumping 150 gallons per minute against a head of 315 feet and delivering into the Yard seam. This pump is driven by a multipolar protected motor of 25 horsepower at 470 volts, when running at 750 revolutions per minute.

There are also two three-throw pumps, with rams, 6 inches in diameter by 9 inches stroke, fixed in the face of the dip-workings of two different districts in the Yard seam each capable of pumping 100 gallons per minute against a head of 100 feet, when running at 40 revolutions per minute. The motors for driving these pumps are of the multipolar type yielding 11½ horsepower at 450 volts, when running at 970 revolutions per minute.

*Electric Lighting.*—A Tyne compound-wound continuous-current dynamo, developing 240 ampères at 105 volts when running at 670 revolutions per minute, is capable of running 400 lamps of 16 candlepower. This dynamo is run by an engine with two cylinders, each 11¾ inches in diameter by 24 inches stroke, at 120 revolutions per minute.

*Ventilation.*—A Capell fan, 16 feet in diameter by 5 feet wide,

is capable of exhausting 200,000 cubic feet of air per minute at 2½ inches water-gauge when running at 168 revolutions per minute. The fan is driven by an engine, with a cylinder, 16¾ inches in diameter by 3 feet stroke, and a flywheel, 12 feet in diameter, running at 84 revolutions per minute.

*Compressed-air Plant.*—A compressor with air-cylinders, and steam-cylinders, 22 inches in diameter by 4 feet stroke, supplies compressed air for driving dip-pumping and coal-cutting machinery.

*Haulage.*—The haulage is effected by endless ropes running above the tubs and attached by means of forks. The engine, situated on the surface, has two cylinders, 14 inches in diameter by 20 inches stroke, geared 10 to 1, and is supplied with steam at a pressure of 80 pounds per square inch. The Cadzow driving-pulley, 7½ feet in diameter, is fixed on the third-motion shaft. The main driving-rope passes down the downcast-shaft and round clutch-pulleys, erected on the shaft-sidings, by which means the haulage-rope in any district may be stopped without stopping the driving-engine. A drum, fixed on the second-motion shaft of this engine, when the driving-pulley is out of gear, enables the engine to be used as a jack-engine for the downcast-shaft.

*Winches.*—For pump and shaft work, there are:—Three steam-winches with cylinders 8 inches in diameter by 12 inches stroke, and double purchase drums 21 inches in diameter by 29 inches wide; also a capstan or crab-engine with two cylinders, 12 inches in diameter by 20 inches stroke, and a drum 4 feet in diameter geared 25 to 1 on the third-motion shaft.

*Boilers.*—The boiler-shed extends the entire distance between the two winding-engines and contains nine Lancashire boilers, 30 feet long and 7½ feet in diameter, three of these work at a pressure of 80 pounds, and six at a pressure of 100 pounds per square inch; and all are fitted with Meldrum forced-draught furnaces for burning duff-coal.

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Mr. C. Liddell read the following paper on an "Apparatus for closing the Top of the Upcast-shaft at Woodhorn Colliery":—

# APPARATUS FOR CLOSING THE TOP OF THE UPCAST-SHAFT AT WOODHORN COLLIERY.

By C. LIDDELL.

At the upcast-shaft, at Woodhorn colliery, the fan-drift is placed below the surface-level, and out of the way of coal-drawing, etc. The fan-drift is walled and arched, and the top of the arch is covered with stones and earth up to surface-level. The fan and its engine are placed some distance from the shaft and clear of the heapstead.

The shaft is enclosed, above the surface, by means of a rectangular framework, *aaaa*, built from iron-girders, *bbbb*, placed across the top of the shaft; and four vertical iron-girders, *aaaa*, are placed at the corners of this rectangle. They form the skeleton-framework, and also carry the cage-buntons, *cc*, and rail-guides to a sufficient height for banking out. They are bolted to cross-girders, and the whole framework is firmly fixed to the pulley-legs. This arrangement of framework is, of course, very much like that adopted at most coal-drawing pits; but as it is erected at the ventilating-shaft, the arrangement must necessarily be enclosed and made air-tight (Figs. 1, 2 and 3, Plate XII.).

Fig. 1 (Plate XII.) shews that the framework does not cover the whole of the shaft, being about 10 feet by 9 feet inside, while the diameter of the shaft is 15 feet. It will also be noticed that the centre-line of the framework is about 17 inches from the centre-line of the shaft. Consequently, there is more room at one side of the cages in the shaft than at the other, and the extra room is utilized for pipes, cables, etc.

The top of the shaft and the bottom of the framework is enclosed in a brick building, 52 feet long, by 17½ feet wide, and 25 feet high (Figs. 1, 2 and 3, Plate XII.). The walls are 2 feet thick, and the top of the building is covered with stout planks, *d*. Each plank is grooved along its sides, and fitted to its neighbour, an iron-strip being placed in the grooves so as to ensure a

minimum of air-leakage. Flatsheets are laid upon and attached to the planks, and this forms the banking-out level. The brickwork is not carried above this level.

The framework is enclosed by rivetting sheet-iron, $\frac{3}{16}$ inch thick, to the girders, forming a rectangular box which extends from the flatsheet-level to the top of the pulley-frame, and just below the pulleys. The height of the framework above ground-level is about 55 feet. The top is also enclosed, with the exception of two holes, 12 inches in diameter, left for the passage of the winding-ropes and of the safety-hooks, when necessary.

FIG. 4.—VIEW OF UPCAST-SHAFT AT WOODHORN COLLIERY.

To allow of the tubs being changed, wooden sliding-doors, *ee*, are fixed into the framework at the banking-out level, one door being placed at each end of each cage. These doors are fitted with iron projecting brackets, *ff*, and when a cage comes to bank it lifts up its own pair of doors, and allows the banksman to change the tubs. On the cage being lowered, the doors fall again into their places. Each door weighs about $1\frac{1}{2}$ cwts.

The brick building, enclosing the lower portion of the framework, allows of cages being changed or repaired, horses or material being sent down or drawn out of the pit, without causing a great inflow of air to the fan from bank. The latter condition

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To illustrate Mr. C. Liddell's Paper on an Apparatus for closing the Top of the Upcast Shaft, etc.

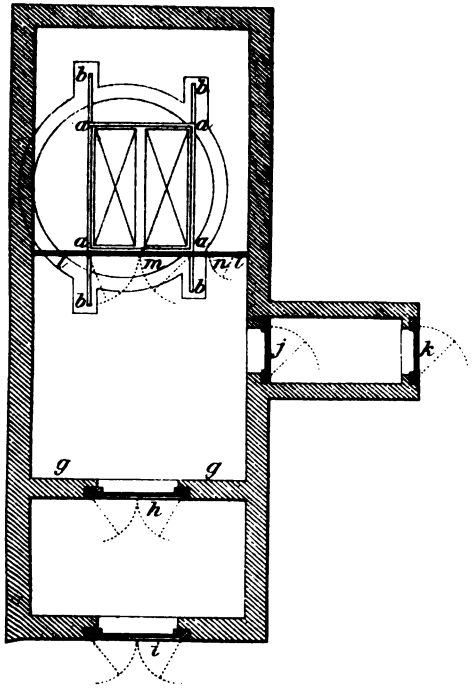


FIG. 1.—PLAN.

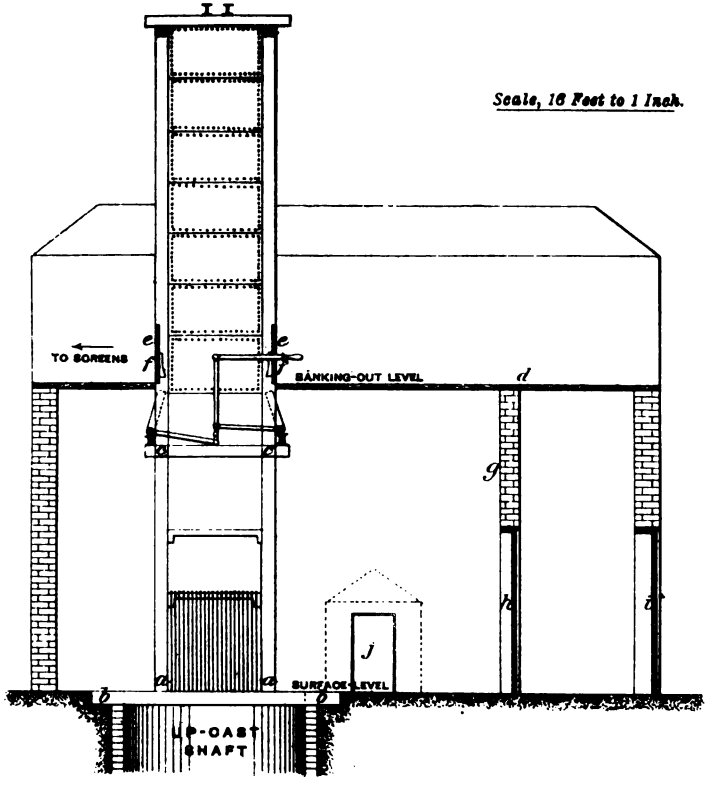


FIG. 2.—LONGITUDINAL SECTION.

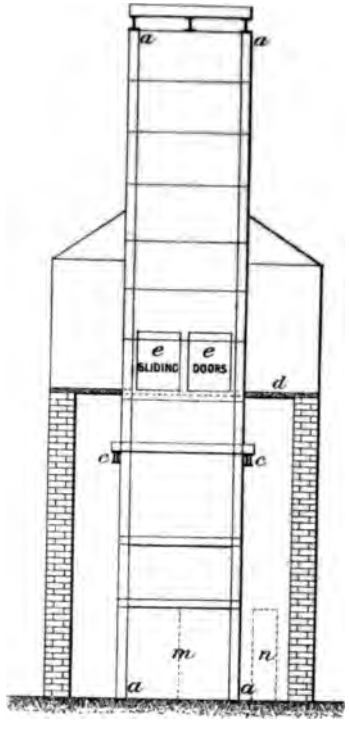


FIG. 3.—CROSS SECTION.

necessitates an arrangement of double doors, so that at least one may be closed while persons are entering or leaving the building. A wall, *gg*, 18 inches thick, is built across one end of the building, fitted with a doorway, *h*, 13½ feet high and 6 feet wide. This partition-wall divides the building into two parts, and a doorway of similar size, *i*, is built into the outer and adjacent wall. A pair of smaller doors, *j* and *k* (7 feet high by 4¼ feet wide), are built into one side of the building, and are used by persons entering or leaving the enclosed building.

In order further to prevent access of air within the building, the framework is cleaded with wood, *ll*, and a pair of large doors, *m*, and a small door, *n*, are erected in the wooden cleading. This arrangement facilitates the opening and shutting of the outer doors.

There are six windows, with iron-frames, built into the side-walls of the building, to admit light in the day-time. Electric lights are used for night-work.

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Mr. T. V. Simpson proposed a vote of thanks to Mr. C. Liddell for his interesting paper, and it was cordially approved.

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# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING
HELD IN THE LECTURE THEATRE OF THE LITERARY AND PHILOSOPHICAL SOCIETY, NEWCASTLE-UPON-TYNE,
APRIL 12TH, 1902.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

## THE LATE MR J. L. HEDLEY.

The PRESIDENT (Mr. J. G. Weeks) said that, since the last meeting, they had lost by death one of their Vice-Presidents, Mr. J. L. Hedley, H.M. inspector of mines for the Newcastle-upon-Tyne mines-inspection district. The members would admit that no one could have discharged the delicate duties of his office with greater firmness and judgment than the late Mr. Hedley had done. In addition to his duties as one of H.M. inspectors of mines he took great interest in the business of the Institute; he had been for many years a member of the Council, and in later years a Vice-President; and his death was a very great loss to them in their deliberations. He (the President) moved that a vote of condolence be addressed to Mrs. Hedley expressing their great regret for her husband's death, and conveying their condolence and sympathy with her in her bereavement.

Mr. T. W. BENSON, in seconding the vote of condolence, said that during the time Mr. Hedley was in charge of the Newcastle district he had endeared himself to all with whom he was brought into contact. He did his work most thoroughly, and yet he never interfered capriciously or unnecessarily with colliery-managers in the discharge of their duties.

The vote of condolence was unanimously adopted.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on March 22nd and that day.

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The following gentlemen were elected, having been previously nominated: —

MEMBERS—

Mr. JOSEPH FENWICK BELL, Assistant Manager, 12, Success Cottages, Fence Houses, County Durham.

Mr. JOSEPH JAMES BURTON, Manager, Cargo Fleet Iron Company, Rosecroft, Nunthorpe, R.S.O., Yorkshire.

Mr. ARTHUR CROSBY, Colliery Manager, 196, Barnsley Road, Pitsmoor, Sheffield.

Mr. MARTIN FISHBACK, Mine Superintendent, Banco Minero, Parral, Chihuahua, Mexico.

Mr. THOMAS JAMES, Colliery Manager, Cae Duke Colliery, Loughor, near Swansea.

Mr. JAMES ALEXANDER MCFARLANE, Mine and Smelting-works Manager, Dzansul Copper-mines, Batum, Southern Russia.

Mr. SAMUEL JOSEPH POLLITZER, Licensed Mining Surveyor and Mining Engineer, Temple Court, 146, King Street, Sydney, New South Wales, Australia.

Mr. HENRY BAKER REYNOLDS, ChemicalEngineer and Metallurgist, Dzansul Copper-mines, Batum, Southern Russia.

Mr. SAMUEL HULME RHODES, Patent Agent, 50, Zimmerstrasse, Berlin, Germany.

Mr. GEORGE HARDY STANLEY, Metallurgist and Mining Engineer, Durham College of Science, Newcastle-upon-Tyne.

Mr. WILLIAM STOREY, Mechanical Engineer, Urpeth Villas, Beamish, R.S.O., County Durham.

Mr. HARRY P. TOWNSEND, Mine Manager, The Penhalonga Proprietary Mines Limited, Umtali, Rhodesia, South Africa.

ASSOCIATE—

Mr. WILLIAM JOHN CHARLTON, Jun., Colliery Surveyor, 17, First Row, Ashington, Morpeth, Northumberland.

STUDENTS—

Mr. P. B. JUNOR, Jun., Mining Student, Thornley Colliery, Thornley, R.S.O., County Durham.

Mr. JOHN WILLIAM ROBINSON, Mining Apprentice, Boldon Colliery Offices, Boldon Colliery, R.S.O., County Durham.

Mr. GEORGE HENRY HALL SCOTT, Mining Student, Cowpen Colliery, Blyth, Northumberland.

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Dr. THOMAS OLIVER read the following paper on "A Visit to the Simplon Tunnel: The Works and Workmen."

# A VISIT TO THE SIMPLON TUNNEL: THE WORKS AND WORKMEN.

By THOMAS OLIVER, M.A., M.D., F.R.C.P.,
NEWCASTLE-UPON-TYNE.

Early one morning in the month of May of last year, having previously forwarded his letters of introduction to the proper authorities, the writer found himself at Iselle, a village on the Italian frontier of the Alps. Gigantic as the engineering enterprise at the Simplon is admitted by all to be, his visit was undertaken less with the object of viewing the tunnelling of this well-known Alpine col than of learning something of the hygienic, medical and social problems raised by the massing together of thousands of workmen in a remote valley, far from the means of supply, and offering at first the scantiest house-accommodation. Until recently, Iselle was an obscure hamlet; to-day, it is a centre of great activity. A large population has suddenly sprung up in and around the village, thanks to the genius of the men who are directing the operations, and yet it has happened to this as to so many of the affairs of human life, that the man who was foremost in developing the scheme, "whose activity encouraged and animated the undertaking," is no longer at the front directing and guiding the operations: Mr. Brandt died in November, 1899. Of the four lieutenants trained in his school, possessed of similar energy, and equally devoted to their work as was their master, it was the writer's privilege to meet at Iselle, Mr. Edward Sulzer-Ziegler, to whom he gladly acknowledges his sense of indebtedness for the trouble taken in coming from Zurich, for the hospitality extended, and the knowledge imparted. To Dr. Volante, the resident medical officer at Iselle, who also accompanied the writer over the works, he also takes this opportunity of expressing his thanks.

As far back as 1859 the tunnelling of the Simplon was suggested by Mr. Flachat, but the proposal was abandoned, owing

to political complications. The subject was again discussed in 1876, when the St. Gothard tunnel was under consideration. Until the St. Gothard was pierced, Switzerland possessed no direct railway communication southwards, as both the Brenner and Mont Cenis railways pass outside its boundaries.

Like the Mont Cenis tunnel, that of St. Gothard is driven in a straight line from end to end, and is constructed for a double line of railway throughout. The actual length of the St. Gothard tunnel is 9·31 miles. In constructing it, the contractors profited by the experience of the 13 years spent in making the Mont

FIG. 1.—SIMPLON TUNNEL-WORKS AT ISELLE, ITALY.

Cenis railway. Substituting machinery worked with compressed air for hand-labour, they were able to complete in less than 10 years a length of 9 miles of tunnel, as against the 8 miles of the Mont Cenis.

The construction of the St. Gothard tunnel was attended by great sacrifice of life. Several of the horses died, and of the workmen it is stated that 600 perished, including the engineer and the contractor. This enormous mortality was attributed to insufficient ventilation, to the high temperature in the tunnel which (before the running of the fan) was often as high as 107° Fahr., with 97

per cent. of moisture, exposure of the miners to the rigours of an Alpine climate on emerging from the tunnel, want of care on the part of the workmen in not changing their wet clothes, the poor character of the food supplied, and also to the ravages of an intestinal parasite, *Anchylostomum duodenale*, which, owing to the uncleanly habits of the miners, gained access through the drinking-water to the alimentary canal of fellow-workmen and literally speaking sucked the life-blood of its host.

The cost of the St. Gothard tunnel was £2,327,000 or only 80 per cent. that of the Mont Cenis railway, although fully 1 mile longer.

The tunnelling of the St. Gothard, which was secured by Germany and Switzerland, diverted to some extent the traffic of France. On economic as well as on international grounds, the completion of the Simplon tunnel is awaited with interest, as when the railway is open it may probably bring back to France some of the trade which she lost through the opening of the St. Gothard route and it will, for Switzerland at any rate, develop fresh lines of traffic by Milan. It will, in addition, shorten the distance between Calais and Milan. By the Mont Cenis railway the distance between these two towns is 680 miles, by the St. Gothard 665 miles, while by the Simplon tunnel it will be 585 miles, or nearly 100 miles shorter than by the longest route.

The Simplon tunnel, which will bring Brigue in Switzerland and Domo d'Ossola in Italy into direct railway connection, the distance between the two places being 41 miles, is being made by Messrs. Brandt, Brandau & Company of Zurich, for the Jura-Simplon Railway Company. For several years, as already mentioned, the matter had been discussed, but the project was dropped, not solely from the great expense likely to be incurred and for political reasons, but among other things, on account of the temperatures likely to be met with in the Simplon being much higher than those in the St. Gothard tunnel. The question of the practicability of the scheme was therefore referred to a small committee, composed of Mr. Francis Fox, of the firm of Sir Douglas Fox and Partners, London, who had successfully ventilated the Mersey tunnel; Mr. Colombo, professor of engineering in Milan, formerly a minister of Italy; and Mr. Wagner, of Vienna, director of the state railways of Austria. This com-

mittee reported favourably upon the scheme, and expressed the opinion that instead of costing 100,000,000 francs it could be made for 60,000,000 francs, also that instead of requiring 8 years to pierce the Simplon the work could be accomplished in 5½ years. Messrs. Brandt, Brandau & Company accepted the contract for 55,000,000 francs for the tunnel alone, plus 10,000,000 francs more for outside railway-lines, that is, 65,000,000 francs or £2,118,000 for the whole undertaking, and they are bound to finish the work in 5½ years, or pay a fine to the Jura-Simplon Railway Company of 5,000 francs for every day of delay beyond the agreed date. The contract was signed by Messrs. Brandt & Brandau on August 13th, 1898, but, as 3 months' grace was allowed before boring operations were to be commenced, the actual work did not begin until November 13th of that year, and it must be completed by May 13th, 1904. It was assumed that 2,000 working days would be sufficient to bore through 12 miles of rock. By working from opposite ends of the mountain the daily average progress was estimated to be 9·8 metres or a little over 30 feet, and it was believed that this rate or more would probably be maintained over the 5½ years.

It was with these probabilities before them that Messrs. Brandt & Brandau undertook the work, not lightly yet hopefully, fully aware of the responsibility and the greatness of the task before them. In discussing with Mr. Sulzer the prospects of the successful tunnelling of the Simplon the reply which he gave the writer is characteristic not only of the man himself but of his firm—"we have gained our experience," he said, "although not altogether personally, from the tunnelling of the St. Gothard; we have profited by its failures; we have learned from that enterprise how not to make a tunnel, and we are trying not to repeat its mistakes."

So strongly impressed were Mr. Sulzer and his colleagues with the importance of having healthy miners for the work, sufficient house-accommodation for them and their families, and above all good ventilation in the tunnel, that before even a clod was turned or a piece of rock broken they appointed two medical men, one at Brigue, the northern or Swiss end of the Simplon, and the other at Iselle, the southern or Italian end of the proposed tunnel, to examine all applicants for work. It is to the extreme care given to all hygienic matters connected with the enterprise, the humane

attention devoted to the workmen, and the fortunate choice of two excellent medical men by the company that, in addition to the great engineering ability of the late Mr. Brandt, of Mr. Sulzer and his colleagues, as well as to the practical skill and endurance of the workmen, is to be attributed the great success which until lately has attended the undertaking.

In winter, the Simplon pass is occasionally snowed up for 2 or 3 weeks at a time, very frequently for 5 or 6 days, and consequently traffic over it is impossible. People wishing to reach the north-west of Italy from Switzerland are therefore obliged to go by the St. Gothard railway, which means an additional 28 hours added to the travelling, to say nothing of the increased expense. When the Simplon tunnel is open, the train will steam through it in ½ hour.

The distance between the two portals of the Simplon tunnel is 12·26 miles or 64,692 feet. At the end of April 1901, that is, in 18 months, a little over 3 miles of the tunnel had been constructed, equivalent to 9,684 feet on the northern side of the Alps, and 7,050 feet on the southern side. The perforation of the Simplon is being made from opposite sides, and each tunnel will meet in the middle of the mountain. Mr. L. Ernst* supplies some facts that enable one to compare the "actual advance made at either end of the tunnel with the daily average that the contractors hoped to make." On the north side, the boring-machines at first encountered a tolerably soft stone and as a consequence progress was rapid enough, often as much as 21·32 feet (6·5 metres) daily, but on reaching the hard rock or gneiss, of which the greatest part of the mountain is composed, the daily average was only 17·32 feet (5·28 metres). On the south side, the Italian government raised objections to the use of dynamite for blasting purposes and consequently progress was at first very slow: but as these obstacles have been removed, and new machinery driven by water-power introduced, the average daily progress in the middle of last summer was 14·77 feet (4·5 metres).

In the construction of some of the older Alpine tunnels "the boring-chisels, faced with diamonds, cut their way into the rock,

* *Die Umschau*, April 13th, 1901, quoted in *Nature*, 1901, vol. lxiv., page 235.

the motive power being compressed air, the compression being effected by hydraulic machinery. Mr. Brandt recognized the loss of mechanical power in this arrangement, and decided to use water-pressure direct on the boring-apparatus. At the same time, he dispensed with the diamond-cutting process, which, by means of rapid rotation, worked its way into the stone as a saw, substituting a hard steel face to the chisel, which is driven against the rock and rotates slowly, about 6 times a minute. . . . Two boring-machines are mounted on each stand and are worked simultaneously. The diameter of each chisel is 4 inches (10 centimetres), and it is driven into the rock a distance of 6½ feet (2 metres). Into the aperture thus formed a cartridge of dynamite is placed and exploded, the rock shattered by blasting has to be removed, and the boring-machine is then pushed forward and the operation continued."* Mr. Francis Fox,† in describing the Brandt rotatory drill, states that it works with a pressure of 10 tons on the cutting-points, that the drills are driven by hydraulic pressure of 100 atmospheres or 1,470 pounds to the square inch, and as the cutter has a ⅜ inch hole along its centre all the waste water is discharged right on to the cutting-edges, thus keeping them cool and washing out a certain amount of débris.

The removal of the masses of rock, broken by the blasting, necessarily involves a great amount of labour and entails stoppage of the boring-machine until the débris has been cleared away. In exploding the blasting-charge, "liquid air or oxygen has been used with good effect." The charcoal covering of the charge is, shortly before its use, steeped in liquid oxygen and the recovery of the gaseous form is said to have the advantage of mitigating some of the evils that the presence of carbonic oxide tends to produce.‡ According to Mr. Francis Fox the time taken for each portion of the attack in the hard Antigorio gneiss is as follows:—Bringing up and adjustment of the drills, 20 minutes; drilling, 1¾ to 2½ hours; charging and firing, 15 minutes; clearing away débris, 2 hours; or a total of between 4½ to 5½ hours, resulting in an advance of 3 feet 9 inches or a daily advance of nearly 19 feet 6 inches. During the month of April, 1901, the daily progress

* *Nature*, 1901, vol. lxiv., page 235.

† *Proceedings of the Royal Institution of Great Britain*, 1900, vol. xvi., page 433.

‡ *Trans. Inst. M.E.*, 1900, vol. xix. page 164.

at each of the two faces averaged 17 feet 3½ inches or a total of upwards of 34 feet, a rate of progress slightly in advance of the speed estimated by the engineers four years ago.

Two tunnels are being made running parallel to each other at a distance apart, from centre to centre, of 55 feet 9 inches, and while each will carry a single line of way, only one of the tunnels is being completed at present. One of the principal features of the Simplon is the much lower altitude of the rails above the sea-level than in any of the other Alpine tunnels. This altitude is at its highest point 2,314 feet, or 1,474 feet lower than the St. Gothard and 1,934 feet lower than that of Mont Cenis, a circumstance of considerable importance from a haulage-point of view. At the Swiss or Brigue end the Simplon is penetrated at the level of the railway; the gradient there is only 1 in 500 or just sufficient for drainage, but in the southern portion near Iselle the gradient is 1 in 142.

The contractors have had to contend with very high temperatures in the tunnel. The surface of the Simplon at its highest point is 6,895 feet above the tunnel or 1,160 feet higher than that of the St. Gothard. Starting from Brigue, on the Swiss side of the Alps, the railway will rise in the summit of the tunnel to 2,314 feet above the sea-level. Two parallel tunnels (as already stated) are being made, and while only one at present is being completed, the other is being utilized for purposes of ventilation. At every 660 feet inside the mountain, the two tunnels are united by cross-headings, by means of which air is carried to the face where the miners are working, and as the tunnelling proceeds and fresh cross-headings are made, the older cross-headings are blocked. Fans are kept running to impel air into the tunnel, so that through these cross-headings fresh air is delivered at the place where the men are at work, and therefore where it is most required.

Jets of cold water, 15·4 gallons (70 litres) per second, and under a pressure of 100 atmospheres can also be made to play at the working-faces, and yet despite these precautions, the temperature in the tunnel has sometimes been as high as 30° Cent. or 86° Fahr. Mr. Sulzer informed the writer that at first the temperature was often as high as 36° Cent. or 96° Fahr., nearly that of blood-heat in man, but that through the use of fans,

the engineers could sometimes keep the temperature as low as 20° Cent. or 68° Fahr. It is common experience that where the air is kept cool, the men are healthier, and they do more work with less fatigue.

Close to the main entrance is another short tunnel called the "gallery of direction," which joins the main tunnel not very far from the portal at either end of the mountain. These two galleries are necessary for the proper alignment of the railway; they contain the observatories, and have been required owing to

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FIG. 2.—SIMPLON PASS, ISELLE, ITALY, X X ARE THE ENTRANCES TO THE PARALLEL TUNNELS.

the tunnel proper making a distinct curve as it is about to emerge from either end of the mountain. At Iselle, the gallery of direction joins the main tunnel about 975 feet from the portal. The main tunnel is fully 18 feet high, while the roof of the gallery of direction is only 7½ to 9 feet from the floor.

At the time of the writer's visit, the gallery of direction at Iselle was being used for taking the miners by rail into and out of the tunnel and for the removal of the rock broken by blasting. There were 1,500 miners employed on the Italian side, divided into 3 batches working an 8 hours shift, so that there are always

500 men working in the tunnel. Consider for the moment what this uninterrupted occupation means, so far as the atmosphere of the tunnel is concerned: 500 men working hard and loading the air with impurities, an equal number of miners' lamps giving off a good deal of smoke, also the combustion-products formed during the explosion of dynamite, and it will be easily recognized from these facts and the effects of high temperature that the men are not only readily overcome by fatigue; but on emerging from the tunnel overheated and exhausted, through working in a somewhat poisoned atmosphere, are prone to become the victims (among other things) of pulmonary disease and rheumatism. As the writer stood in the tunnel by which the vitiated air was escaping in dense whitish-grey clouds, he experienced the sensation that not only had the air a repellent odour, but an indescribably unpleasant taste, saturated as it was with the products formed by the nitro-explosive compounds. Standing in the main tunnel, which is the outlet for the bad air, he had placed himself in the worst position possible, and it would be as unfair to draw conclusions from the condition of the air here as regards the ventilation of the Simplon tunnel, as it would be to form an opinion of the purity of the air circulating in a north-country coal-pit, by analysing the air escaping from the upcast-shaft. It is the experience of the engineers at the Simplon tunnel that the miners are capable of doing in 1½ hours as much muscular work as other men did during 5 hours in the other Alpine tunnels. For every cubic foot of air that was sent into the St. Gothard, 50 cubic feet are being introduced into the Simplon tunnel.

The train that brings the workmen out of the tunnel pulls up at a covered, wooden platform so that the men, wearing their wet clothes, alight from the train without becoming chilled. From the platform most of the men pass directly into a large wooden building which is suitably warmed inside, and part of this building is divided off into 32 cubicles, each of which is fitted up with hot and cold water douche-pipes. In this warm and well ventilated bath-house there are 2,000 cords running up to the ceiling. To the free end of each cord, as it hangs over a pulley, are affixed a leaden soap-box, also 3 hooks upon which are suspended the cap, boots and ordinary wearing clothes of a miner who at the time is working inside the tunnel. On coming out of the

tunnel, the men change their wet clothes in this house, have a warm bath, put on their warm, dry, wearing-clothes and hang up their wet working-clothes, which are found dry and warm again by the miners on returning to work on the following day. The men bring their own towels and soap. Mr. Sulzer told the writer that the firm got the idea of the bath-house and vestiary from a large coal-mine in Westphalia. The floors of the bath-houses are cemented: they are flushed and well cleaned, after the departure of each batch of men. The writer found everything in excellent order and extremely clean. Leading out of the bath-house was a

FIG. 3.—INTERIOR OF BATH-HOUSE AND VESTIARY, SHEWING CORDS AND SUSPENDED CLOTHES.

laundry for washing the hospital linen, fitted up with the drying arrangements that are usually found in large and well-conducted laundries.

The next door on the railway-platform opens into the engineers' bath-house. The interior is partitioned off into small rooms each of which contains a zinc bath, and is provided with spray and douche-pipes, etc. There is also a room where first aid can be rendered to workmen after an accident.

As the tunnelling operations of the Simplon, especially at the Italian end, have had to be conducted in a remote and sparsely populated valley, the contractors have had of necessity to provide house-accommodation for the workpeople and their families. Most of the workmen are married. Messrs. Brandt & Brandau prefer married men; they work better, are more reliable, and they are more likely to remain. Houses have been erected for both married and unmarried men. The unmarried men live in a kind of barracks; some of the rooms contain 4 to 6 beds. Speaking generally the writer found these rooms very clean. One large, wooden building had been erected to accommodate 120 unmarried men, but a very large number of the unmarried miners shun barrack-life. It reminds them too much of their previous military experience when they were conscripts. Some of the rooms in this building have, therefore, been let to married men with small families. Where this has been done, the writer usually found one large and one small bed in a room, also a good cooking-stove, along with the few bits of furniture that the people had scraped together, never very much. For one of these rooms a married miner pays 7 francs a month. In the unmarried men's rooms there were never fewer than 4 beds. The company provides the beds and bed-clothes, and for the sleeping accommodation thus afforded and for board, the unmarried miner pays 1 franc a day.

In addition to the above there are numerous small, flat-roofed, wooden houses for married men. These contain 2 rooms—1 front and back. Sometimes the people who rent these houses take in lodgers. In the front room, which serves as the kitchen as well as a sleeping room, the writer usually found one bed, while in the back room there were 2 beds. It is in these houses that over-crowding goes on to some extent, which the company does its best to discourage. In some of the back rooms for example, the writer found 3 beds and 1 large crib separated from each other by a space little more than sufficient to stand in. At Iselle, a short while ago, the company built 60 of these houses.

The hospital at Iselle is a neat, wooden two-storied building and contains 24 beds, 4 of which on the day of the writer's visit were occupied. The two wards, each of which contains 12 beds, are extremely clean and well kept. There are bath-rooms leading from the end of the wards. The operation-room is extremely

clean, and is furnished with a neat, polished, glass cupboard containing surgical instruments, all of the most modern make. Everything is supplied by the company. It was interesting to observe that in this remote part of Italy the antiseptic treatment of wounds is carried out with a fidelity that would give gratification to Lord Lister, and compares most favourably with the system adopted in the largest and best equipped infirmaries in Britain. The doctor's house is part of the hospital building. There is a telephone from the hospital to the installation-plant, and from there into the tunnel where the men are working. All medical

FIG. 4.—INTERIOR OF HOSPITAL, ISELLE, ITALY.

and surgical help is given to injured married workmen free of charge and without any reduction of their wages, but the unmarried men pay 1 franc a day for their food since they receive half of their wages. In Italy, since 1898, there is a law which makes provision for injured workpeople; Switzerland also has its Compensation Act. In Italy, the law allows to an injured workman half of his wages and a doctor's attendance until he is recovered, but if he is permanently incapacitated, the maximum to which he is entitled is 1,500 times his daily wage or 5 years' income. In the case of an accident, at the Simplon tunnel,

incapacitating a workman, there is an enquiry made by a responsible official who reports upon the case to the firm. A medical report is also furnished.

At Iselle, the workmen are all Italians; they looked well and seemed to be healthy, wiry men. In the tunnel, the work goes on day and night, Sundays included. The men on outside work have every second Sunday off. The miners change their shift every fortnight: the hours of entering the tunnel are 6 a.m., 2 p.m. and 10 p.m. A miner's wages usually runs from 3·60 to 4 francs per day and although this amount (3s. to 3s. 4d.) is not large, yet living at Iselle is, considering everything, cheap. There is no difficulty in getting plenty of workmen and although the wages seem small, yet, when the men are temperate, they are able to save and to send money home to their relatives in other parts of Italy. To the miners who are working at the face, Messrs. Brandt & Brandau give a premium when more than the daily average progress is made, and in a general way it may be stated that the firm is paying the workmen more than they would receive if engaged in similar work in any other part of Italy. At Iselle, the workmen at the time of the writer's visit were paid once a month, but if they wished it, they could obtain an advance at the end of a fortnight. Until recently, the company had stores, where goods could be bought or got on credit, the company giving coupons to the miners.

So far, the construction of the Simplon tunnel has been remarkably free from loss of life, considering the large number of men employed at Iselle (nearly 2,000) and the extremely hazardous nature of their occupation. There had been from November, 1898, until the end of May, 1901, only 6 deaths from accidents. Three of these deaths occurred in the tunnel, and 3 in making the galleries. Dr. Volante told the writer that from January to June, 1901, there had been neither death nor permanent injury consequent upon any accident.

There have been plenty of minor accidents. The most common accidents are those to hands and fingers, and, next to these, injuries to the head, by falling stones, and injuries to the legs caused by wagons. There have been no accidents from explosives, except two: one where a miner in the tunnel had transgressed the

company's rules and bored into an old hole which had not been fired, while the other occurred during the tipping of débris down an embankment. Among the loose stones removed from the tunnel there had lain concealed some unexploded dynamite. Particular care is now taken not to allow any frozen dynamite to enter the tunnel.

Of the diseases to which the Simplon miners are especially liable, Dr. Volante considers bronchitis and rheumatism as the most frequent. Intestinal catarrh, owing to rapid variations of temperatures, is also common. Heart disease is rare, owing to the fact that before a new hand is taken on he is medically examined by Dr. Volante. The drinking-water at the Simplon tunnel is good, and as a consequence there has been no enteric fever in the company's houses. One of the scourges of the St. Gothard miners was the intestinal parasite *Anchylostomum duodenale*. It is very strong testimony to the vigilance of Drs. Volante and Pommata, knowing how very frequently anchylostomiasis is found among the peasantry and labourers of Piedmont and Italian miners generally, that the workmen at the Simplon should until now have escaped this pest.

After making as careful an inspection of the works at Iselle as time permitted, the writer drove over the Simplon pass to Brigue, the Swiss side of the mountain. In good weather the drive over the Pass is usually accomplished in 10 or 12 hours. On the following day, he called at the office of Messrs. Brandt & Brandau, close to the tunnel, and, accompanied by Mr. Kleinert, made a round of inspection. The works here are practically a repetition of those which the writer has described as existing at Iselle. More men are employed. Of the 3,000 workmen employed at Brigue, 1,500 work in the tunnel, 500 on each shift of 8 hours. Close to the mouth of the tunnel is a long, wooden building with an enclosed railway-platform. Here the men enter and alight from the railway-trucks that take them into and bring them out of the tunnel. Here too are the rooms that are set aside for the medical examination by Dr. Pommata of all applicants for work. In addition, there is a room for rendering first aid to the injured, a bath-house with vestiary for the workmen similar to that at Iselle, while a little farther down the valley are the offices and work-

shops of the company. At the time of the writer's visit, ther was a good deal of water in the tunnel, especially at the Brigu end. Mr. Kleinert informed the writer that about 75 per cent. o the men took the baths on coming from work. Ever since a strike that occurred here in October, 1899, the men receive their wage weekly. The wages at Brigue are a little higher than at Iselle The miners are all Italians. They can make 25s. (30 francs) a week, sometimes more. In May of last year the men were work ing in the mountain 3 miles from the portal.

The company's hospital at Brigue is a little larger than tha at Iselle. There were 17 patients in the wards at the time of th writer's visit; and 5 of the cases were surgical. Leaving th hospital, the writer proceeded to Naters, the Italian settlemen just across the river Rhone, and visited the unmarried men' canteen and sleeping-house. The large dining-room is capabl of accommodating 130 workmen. For 5d. (50 centimes) an workman can get a good meal of soup, meat, vegetables and bread Eighty unmarried men were staying in the barracks, which is a two-storied building with central corridors from which the bed rooms on either side are entered. The rooms and corridors are li by electricity. For food and a share of a bedroom the men pa 11d. (1·10 francs) per day, or 1d. more than at Iselle. The bedroom are clean, and so too is the bed-clothing. On going to work th men give up the key of their room to the head-porter, who tol the writer that on the whole the miners were well behaved, an that, comparatively speaking, there had been very few thefts i the barracks.

Here, as at Iselle, there are also rows of low flat-roofed house for the married men. The houses were made purposely single storied, so that the men, returning from work when on the nigh shift, might enter their homes without disturbing the sleep o other workmen.

At Brigue, as at Iselle, speaking generally, the writer wa struck by the fact that over and above all the engineerin difficulties that had to be grappled with, Messrs. Brandt, Brandau & Company had from the commencement made hygienic question their primary consideration, and had made as ample house-pro vision for their workmen as they possibly could.

Although the miners at Iselle and Brigue are all Italians, i

is to be remembered that they have been drawn from various parts of the peninsula, including Piedmont, Lombardy, Venice, Naples and the south. Speaking different dialects they not only do not mingle in a friendly way, but they vie with each other in regard to local customs, etc. The presence of so large a population of Italian workmen on the Swiss side of the Alps raises questions that are both social and economic, for apart from the tunnelling of the Simplon, Italian workmen have for years past been emigrating into Switzerland in large numbers and have carried with them their language, habits, customs and politics, and too often underpaid labour.

Before closing this paper, the writer may briefly allude to two other circumstances that ought to be of interest to mining-engineers. In June, 1901, a strike occurred at the Simplon tunnel. As is well known, the supply of Italian labour is abundant, and can be very readily replaced. On June 13th, 1901, the stonemen refused to work, and absented themselves until the 19th. On June 20th, all the men in the tunnel had struck work, but by July 6th, most of them had returned. The first strike was preparatory to the other, although it ought to be mentioned that the stonemen resumed work without having obtained any of the concessions that they demanded. A certain amount of intimidation had been used. Ninety per cent. of the workmen were in some mysterious and unaccountable manner persuaded to give up work without presenting any demand, or offering any explanation to the company. Secretly many of the men intimated to the firm their willingness to resume work. Two days after the strike commenced a wellknown socialist—Cattaneo from Milan—appeared at Iselle and presented five demands to Messrs. Brandt & Brandau. These were:—(1) An increase of pay from 20 to 25 per cent., (2) reduction of working hours, (3) payment of full wages during incapacity from injury, (4) abolition of coupons for the stores, and (5) abolition of piece-work. Before June of last year, the coupon-system had been abolished; and Cattaneo, who had arrived from Milan only the day previous to that on which he sent in his demands, showed himself to be ignorant of the local conditions at Iselle. He had simply constituted himself the spokesman of the workmen, and framed a series of claims to which he thought the men were entitled. He based his claims for

larger wages for the miners upon the dangerous nature of their calling. Only a few months previously the miners had received an increase of 25 per cent. on their wages for an 8 hours' day. The foremen were receiving 9s. 2d. (11 francs) daily, miners 5s. (6 francs) and helpers 4s. 2d. (5 francs) but during the month immediately preceding the strike the men were working 6 hours' shifts and not 8 hours, owing to a large influx of water into the tunnel. The contractors had never refused to listen to any reasonable demands from the men; and Cattaneo admitted that Messrs. Brandt & Brandau had shown a humanitarian spirit, and had always exhibited a sympathetic interest in the men during their illness. He also acknowledged that the workmen at the Simplon were better paid than men similarly employed elsewhere in Italy. The miners had some months previously been receiving 2s. 11d. (3½ francs) daily, but for a short period before the strike their wages had been raised. The men who incited the workmen at the Simplon to strike were receiving smaller wages, yet they themselves did not strike. They were possessed of only one idea, namely the belief that Messrs. Brandt & Brandau were likely to pocket £400,000 (10,000,000 francs) out of the undertaking and they, therefore, wanted to make the firm pay £80,000 (2,000,000 francs) more to the miners in wages. Meanwhile the company paid all arrears of wages, dismissed the workmen, and opened new lists on July 5th for men who were willing to resume work. Of the 2,047 workmen who gave up their employment on June 20th. 1,570 men had returned to work by July 15th. Fifty were not taken on again, while 427, several of whom were the best workmen, had left Iselle. The strike was brought to a close without violence or bloodshed. From £2,800 to £3,200 (70,000 to 80,000 francs) were lost in wages, and about 500 of the workmen in one way or another lost their employment.

Hardly had this episode closed when there occurred what cannot but be regarded as a disaster, and this is the second point to which the writer intended to allude. Work had been resumed in the tunnel and rapid progress was being made, for the contractors were some distance in advance of the estimate as regards time, when, at first gradually and then rather suddenly, there occurred a tremendous inrush of water into the tunnel. Hitherto the rock had been very hard gneiss. It was known that

at a particular part of the tunnel a large body of water would be encountered, and that there would be both trouble and inconvenience from it, but the rush of water into the tunnel during the night of September 30th, 1901, was greater than was anticipated. The influx did not seem to come from any accumulation of water on the surface. As the miners had penetrated rock no longer gneiss but limestone, it was believed that there were large cavities in these beds which were filled with water and that some of these had been tapped. The water broke into the head of the main tunnel, but it did not extend into the parallel gallery where the men were still able to carry on their tunnelling operations. By November 10th an advance was begun by hand-drilling and 5 days afterwards the machine-drills were again at work in the principal tunnel. Since then there have been frequent inrushes of water, and progress had been considerably retarded, but despite all obstacles it is to be hoped that Messrs. Brandt & Brandau will on May 13th, 1904, see the undertaking, they have begun, carried to a successful termination.

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Dr. T. Oliver (Newcastle-upon-Tyne) stated that since his paper was written, he had received from Mr. Francis Fox further information relating to the progress of work in the tunnel. At the end of February last, the gallery at Brigue had reached 22,025 feet (6,713 metres). If to this be added 591 feet (180 metres) for March, the tunnel at the northern end has advanced 4½ miles. At the Iselle end, the distance reached is 14,534 feet (4,430 metres) or just a little less than 3 miles. This makes a total of 7½ miles out of the 12·2 miles to be excavated. At the Brigue end, the daily average at present is 20 feet (6 metres) a day.

In a recent letter to the writer, from Dr. Volante of Iselle, it is stated that the quantity of water in the tunnel as Iselle had not interrupted the work lately to any great extent, and that while there was water in one of the tunnels, the other, fortunately, was quite dry. The greatest inconvenience of late had been caused by the miners encountering a very soft and friable stone, which had necessitated new methods of working. Now that more solid rock had again been met, the hope was expressed that in a little time the operations would be renewed with the older methods, and lost time regained. The disaster to the Simplon

tunnel had been followed by one compensating circumstance, namely, the temperature had been much lowered, owing to the large quantity of water in the tunnel; and as a consequence there had been very much less sickness among the miners than on any previous occasion.

The PRESIDENT (Mr. J. G. Weeks) in moving a vote of thanks to Dr. Oliver for his valuable paper, remarked that one of the objects of the Institute was the preservation of human life. Dr. Oliver had shown that the Swiss engineers directing the Simplon tunnel-works had the same object in view, and had been most successful in accomplishing it. They had started by securing healthy workmen, next they gave them good air and good water, and finally they saw that they were provided with good houses and good food. The fewness of accidents was remarkable, considering the number of workmen employed; and the engineers were to be congratulated on the success that had attended their efforts. Very satisfactory progress had been made with the tunnel, seeing that $7\frac{1}{2}$ miles had already been completed, leaving only $4\frac{3}{4}$ miles still to be completed; it might, therefore, be reasonably hoped that the great international road would be completed within the fixed time. Engineers, who assisted in bringing countries into closer communication with each other, were doing great international work and forwarding civilization. He asked Dr. Oliver whether the tunnel was electrically lighted.

Dr. OLIVER replied, only to a certain extent.

Mr. T. E. FORSTER seconded the vote of thanks, which was very cordially adopted.

Dr. OLIVER, in acknowledging the vote of thanks, said that he had visited the tunnel-works from the hygienic and social side, and he had been particularly pleased with the successful manner in which the company had attended to these requirements for their workmen. It redounded greatly to the credit of the contractors that, up to the present time, there had been so few accidents at the works. Mr. Sulzer had told him that they were glad to find the hospitals were so large, a remark which shewed the character of the man and of his firm.

## DISCUSSION OF MR. W. O. WOOD'S PAPER ON "THE SUSSMANN ELECTRIC MINERS' LAMP."*

Mr. JAMES ASHWORTH (Derby) wrote that Mr. W. O. Wood, in the concluding paragraphs of his paper, showed that however desirable a Sussmann or other electric miners' lamp might be, yet that it was necessary, and in accordance with his experience, to provide oil safety-lamps for the deputies to visit and examine the working-places, before the commencement of and during the shift; and also that the putters must use oil safety-lamps, in order that the hewers could use them to examine their working-places, if they suspected the presence of gas. Unfortunately, Mr. Wood did not say what type of oil-lamp he used for the purposes of examination, but one was led to the conclusion that it was not a modern gas-detector oil-lamp; or a careless man could not have been found with the gauze of his safety-lamp red-hot, in a place which had suddenly become foul.† This possible occurrence could not happen with an electric lamp, as Mr. Wood justly observed; and with equal certainty it might be asserted that it could not occur with a modern up-to-date safety-lamp, properly designed for the detection of fire-damp, or for use by putters. Many mining-engineers rightly hold that every working-place should be provided with at least one lamp which is as capable of making a close examination for fire-damp, as the lamp used by the deputies who have to make the regular and official examinations for fire-damp. In connection with this necessity for making close and accurate tests for fire-damp, it is a most curious fact that the best means for the quick and accurate detection of small percentages of fire-damp are to be found in mining districts where very little fire-damp is given off, and not in those districts which are notorious for huge outbursts, and where the return-air currents are always more or less fouled by fire-damp. Cases have been made public where the whole of the return-air in the upcast-shaft was charged to the extent of ½ to 2 per cent. of fire-damp, and yet the safety-lamps used, for examinations before shot-firing, were the bonneted Clanny, or the bonneted Davy lamp with a movable glass (which is probably one of the most dangerous forms of safety-lamp used in a fiery mine).

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* *Trans. Inst. M.E.*, 1901, vol. xxi., page 189.

† *Ibid.*, pages 193 and 194.

## DISCUSSION OF MR. A. L. STEAVENSON'S PAPER ON "THE CARBONIFEROUS LIMESTONE QUARRIES OF WEARDALE."*

Prof. G. A. Lebour (Durham College of Science) wrote that he had read Mr. A. L. Steavenson's paper with much interest, and he wished that a similar account could be written of every mine and quarry, by the man who knew most about it. It is stated that the "Main Block" of the thick limestone "consists of 18 beds, for which the quarrymen have separate names."† The subdivisions of the rock are really of great interest, and in his notes, he (Prof. Lebour) found the following names, namely:—(20) Fine Posts, (19) Toby Giles, (18) Crabby, (17) Mucky Posts, (16) Pea Post or Rose Mary, (15) Elsy, (14) Thin Cockle Post, (13) Thick Cockle Post, (12) Two Toms, (11) Black Beds, (10) Five Thin Posts, (9) Dun Kit Post, (8) Dun Kit's Bastard, (7) Dun Jim, (6) Stiff Dick, (5) Whaley, (4) Yard Post, (3) Jack Post, (2) Newcastle Post, and (1) The Bottom Post. Here are 20 or 24 divisions, if No. 10 be counted as 5. Now he would much like to know whether Mr. Steavenson's 18 beds have the same names as these and which are which, also the meaning of some of the names. The Pea Post is no doubt so called owing to the sections of *Lithostrotion* which look like peas, the Cockle Posts because of the *Productus*-shells in them, but several of the others require explanation.

Geologists are now taking up the study of zones in the Carboniferous rocks in real earnest and it is by noting all the peculiarities of subdivisions like these that the work can be best furthered. Fossils collected from any one of these courses exclusively would be of great value. It is obvious that each layer is recognizable in some way, or the quarrymen would not have named them separately.

In Weardale, the Great Limestone is at its thickest—thinning away to the southward into Yorkshire and to the northward into Northumberland—and therefore it is there that the type-zones should be carefully worked out first. The beds which one can make out in Tynedale, though much fewer, will probably represent some of the Weardale beds and we want to know which.

Could Mr. Steavenson state whether the subdivisions, in the

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 115.

† *Ibid.*, page 121.

limestone (especially the minor ones) could be followed from quarry to quarry, and if so, how far; whether any are lost or become merged in others; whether the characters show any change as they are followed; etc.,—any answers to such questions would be most valuable.

It is suggested that the bed of gannister 100 feet below the Brockwell seam may be the same as that from which the Dinas bricks of South Wales are made.* This really is inconceivable, though it may of course be that both beds occupy, accidentally, a somewhat similar position in the Carboniferous series, though even this is unlikely. To correlate any stratum in the Carboniferous rocks in the North of England with any deposit in South Wales is, and he firmly believed always would and must be, an impossibility.

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## DISCUSSION OF MR. W. C. BLACKETT'S PAPER ON "A METHOD OF SOCKETING A WINDING-ROPE, ETC."†

Mr. H. W. Hughes (Dudley, Worcestershire) wrote that Mr. Blackett had described in an interesting manner the actual method adopted by him, and there could be no doubt that it was an improvement upon the split-socket or any method in which rivets were employed. He had been using solid sockets or cappings for a number of years, and for guide-ropes, which are tightened by weights, he used the same method as that described by Mr. Blackett; but for winding-ropes he preferred to bend back the strands, as well as to insert a plug. All the cappings were made of best Lowmoor iron, and the larger ones were always strengthened by shrunk-on bands or rings. The method of capping was as follows: The end of the rope was cut off and the capping threaded on and pushed some distance up the rope. Number one strand was bent back forming a loop, and the whole of the wires were threaded beneath the second strand, brought to the outside again, and then half of their number was cut off. The remainder were again passed beneath the same strand, and finally the ends were tucked in. This was repeated with each strand, and finally a conical wedge, about 5 inches long by $\frac{3}{4}$ inch in diameter at its largest point, was driven into the core. The practical result was

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 116.

† *Ibid.*, 1901, vol. xxiii., page 10.

to form a very near approximation to a conical knot, which was then drawn into the capping. Everything depended upon the skill of the workman who made the knot, because it is of the greatest importance that each strand should be evenly and uniformly bent back, in order that it may take its share of the load; if not, the strain on each strand becomes unequal, one is pulled out more than another and the rope shows signs of failing. He had never had a single instance of a capping drawing from the rope, and under actual tests the worst results had shewn that a capped rope stood 73 per cent. of the total breaking-strain of the rope.

Mr. W. C. Blackett was pleased to find that Mr. Hughes approved of his method. The bending back of wires seemed undesirable, and Mr. Hughes supplied one excellent reason, in showing that he was so dependent on the skill and care of a workman, and even with the greatest care, the strain on the strands or wires would almost necessarily seem to be unequal. Whereas it would be seen in the rope-end illustrated in the *Transactions*, with the melted metal run carefully into the wires of the rope, that the strain naturally became equalised. He (Mr. Blackett) could only suggest that the Institute should make comparative tests of methods of capping on the principle of "pull devil, pull baker." He would be very pleased to co-operate.

Mr. Herbert Perkin (Leeds) wrote that Mr. Blackett's interesting paper draws attention to a subject of great practical and scientific value. It is not uncommon in the Midland counties, after turning the wires back to form the cone in the usual way, to run in a mixture of lead and antimony, and this method is adopted at the Yorkshire College when testing wire-ropes, and they very rarely draw out of the lead cone. It would be interesting, if Mr. Blackett would give the composition of the white metal.

Some few years ago, the writer had the opportunity of seeing four samples of rope-capping tested to destruction in the testing-machine at the Yorkshire College.* The wire-ropes had a breaking strain in each case of 30 tons and the caps were supposed to be suitable for this strain, the results of the experiments were as follow:—

* The tests were made by Prof. John Goodman on samples supplied by Prof. Arnold Lupton.

| Method of Attachment. | Breaking Strain of Wire-rope. Tons. | Greatest Load. Tons. | Efficiency. Per Cent. | Remarks. |
|---|---|---|---|---|
| Eye spliced in. | 30 | 26·7 | 89 | The splice gave way. |
| Capel, with collars, but without rivets. | 30 | 8·5 | 28 | The rope was pulled out. |
| Capel, with rivets. | 30 | 14·9 | 50 | The top rivet was sheared, and the rope was pulled out. |
| Conical socket, with wires bent back, but without rivets. | 30 | 10·5 | 35 | The rope was pulled out. |

These tests bear out Mr. Blackett's opening statement as to the need of more efficient capping of winding and hauling ropes.

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## DISCUSSION OF MR. W. B. WILSON, JUNIOR'S, PAPER ON "TAPPING DROWNED WORKINGS AT WHEATLEY HILL COLLIERY."*

Mr. Robt. Broom (Fauldhouse) wrote that in opening out workings in the Kiltongue seam at Heatheryknowe colliery, Lanarkshire, he had occasion to drive to the dip, alongside of old workings full of water, which levelled out at the pit-bottom; and as the workings dipped 1 in 6 for 1,800 feet, the farther they progressed downhill, the greater the head became. The feeder from the old workings was 60 gallons per minute. He used the Mitchell boring-machine, which had been in use in that part of the country for about ten years or so.† The Kiltongue coal-seam had the following section:—

| | | Ft. | In. |
|---|---|---|---|
| *Roof:* | Fakey rock ... ... ... | — | |
| *Seam:* | Hard splint ... ... ... | 1 | 3 |
| | Blue rib ... ... ... | 0 | 2 |
| | Free coal ... ... ... | 1 | 0 |
| | Blaes and fire-clay ... ... | 1 | 0 |
| | Bottom coal, soft .. ... | 3 | 0 |
| *Thill:* | Hard fire-clay ... ... ... | — | |

The holes were bored in the free coal, 1 foot thick, below the blue rib and above the blaes and fire-clay, and there had been no difficulty so far from the holes getting out of their position. The longest hole, which ran off part of the water due to a vertical head of 60 feet was bored for a length of 145 feet, without taking off any

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 72.

† This boring-machine is similar in principle to that shewn in Fig. 1.

coal or removing the machine from its first position. The fact of the rods being hollow to the point of the drill, and that the machine, at the same time as it cut, forced a proportionate supply of water through the rods, prevented any clogging, which he considered would be the chief hindrance in using the Burnside machine. He had bored many holes during the last two years, and he found that a pair of men could readily bore from 50 to 60 feet per shift of 8 hours. He was in the habit of widening out the mouth of the hole for a length of 6 feet, and inserting a length of pipe, 3 inches in diameter, fitted with a tap, by means of glands on the outside, and boring through the pipe with the tap open.

Mr. G. L. KERR (Glasgow) wrote that, although the Burnside safety-boring apparatus appeared to have done the work fairly well under the circumstances, it seemed to him that it was not so suitable for such work as some other machines used for the same purpose. While he had had no practical experience of this machine, yet on reading over the description of it and looking at the drawings, it would appear to be rather a complicated machine for using at such work as tapping wastes. An apparatus of this kind should have simplicity of structure, combined with efficiency and smooth working. The defects in the Burnside machine seemed to be:—(1) That the drilling-machine is working on a fixed or rigid stand; (2) that a considerable amount of preliminary boring has to be effected before the Burnside machine can be used, entailing extra labour and expense; and (3) the difficulty there appears to be of keeping the rods from running out of the proper angle into the roof. This latter point was brought out by Mr. Wilson where he stated that: "Considerable difficulty was, at first, experienced in boring holes as long as was desired, without their penetrating into the roof of the seam."* Now when this occurred it entailed much inconvenience, in addition to the extra labour and cost incurred in withdrawing the rods and starting another hole at the proper angle. This fault, he thought, might be due to the distance at which the working part of the drilling-machine was placed from the coal-face. The weight on the rods between the rigid stand and the coal-face would in itself be sufficient to depress the boring-rods in the entering hole and tend to make them bore in a direction inclining towards the roof. This defect could in his (Mr. Kerr's) opinion be remedied considerably,

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 76.

if the drilling-machine was fitted in some way on to a movable bogie or carriage, so that it could be moved forward as the boring proceeds. Mr. Wilson did not explain very clearly how the débris was removed from the boring, all that he said on this point being that "the tap, N, may be left open while drilling a horizontal hole, in order that the drillings may escape, if there be sufficient water to bring them out, and the tap, P, may be used for the same purpose in the case of a vertical hole." He (Mr. Kerr) would be glad of further information on this point, because in the case of a long hole, if the drillings were not regularly discharged, the drilling-machine would be soon stopped, and great difficulty would be encountered in withdrawing the rods.

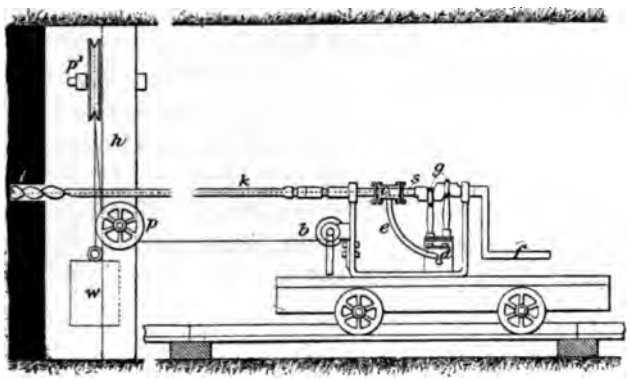


FIG. 1.—COAL-BORING MACHINE. SCALE, 2 FEET TO 1 INCH.

In some of the mines in Scotland, where water had to be tapped from waste or waterlogged workings, a drilling-machine was used which seemed to be simpler in construction and more easily worked than the one used by Mr. Wilson. He (Mr. Kerr) saw one of these machines at work quite recently in a colliery in Lanarkshire, and no difficulty was experienced in boring holes 140 and 150 feet in length.* Several machines of the same type are in use, but they vary very little one from the other in the essential working parts. The drilling-machine consists of a cylinder, *c* (Fig. 1), $1\frac{1}{2}$ inches in diameter, furnished with packing-glands through which a spindle, *s*, connected to the boring-rods, is worked. Fixed on the frame is a pump-chest, *d*, which is connected to the cylinder, *c*, by means of an indiarubber pipe, *e*, $\frac{3}{4}$ inch in diameter. In this pump-chest are two small plunger-

* *Practical Coal-mining*, by Mr. G. L. Kerr, page 27; and *Trans. M.I. Scot.*, 1891, vol. xiii., page 81.

pumps, 1 inch in diameter by 1 inch stroke. These pumps are worked by two cranks on the spindle, *s*, and are supplied with water by a pipe from a cistern. On the outer end of the spindle is a handle, *f*, for working the drilling-machine. The whole apparatus is placed on a tram, running on ordinary pit-rails. The machine is kept moving forward, while the drilling proceeds by means of a chain fixed on to a barrel, *b*, fitted with a ratchet-wheel. The chain passes round two other pulleys, *p*, $p^1$, fixed to a prop, *h*; and a weight, *w*, is hung at the other end of the chain. The rods, *k*, which are hollow, are $\frac{7}{8}$ inch in diameter outside, with an opening $\frac{1}{2}$ inch in diameter, and are made in 6 feet lengths. They are connected to each other by the ordinary method of screwed ends. The drill, *l*, also is hollow and $1\frac{1}{2}$ inches in outside diameter, and is of the ordinary kind used for drilling holes, except that $1\frac{1}{2}$ inches from the point is an opening which allows the water to escape. In applying this machine, the handle, *f*, is rotated, and this in turn works the cranks, *g*, attached to the two force-pumps, *d*, which force the water into the cylinder, *c*, and thence into the hollow rods, *k*, which carry it forward: it is discharged near the point of the drill, *l*, and flows back through the hole, carrying the drillings along with it. This continual flow of water in the hole not only enables the machine to discharge the débris automatically, but it also enables the drills to work more freely and quickly than if the hole were dry. The same principle is here applied as in the diamond-drill process of boring, where the débris is washed away by a continuous stream of water. Holes, 170 feet in length, have been bored by this machine without any difficulty, the rate of cutting varying from 60 to 90 feet per shift of 8 hours, two men being employed at the work. In a recent boring by one of these machines the hole was drilled for a distance of over 140 feet in a seam dipping about 1 in 6, and where the hole had entered the old workings, it was afterwards found to have deviated very little from the angle at which it was set away. No special precautions were taken, with the exception that the machine was kept at the same angle as the dip of the seam. The machine can be used in either coal or ordinary strata.

It might interest members to know that tapping wastes had also been accomplished by using a diamond drill, used much in the same way as they are employed at the surface, but of course the plant for underground work was smaller than that used for drilling

vertical holes from the surface. At a colliery near Glasgow this method was employed, very successfully, to tap water in old workings. The power for driving the drill was supplied by a Priestman oil-engine, developing 3½ horsepower, with a consumption of 3 gallons of oil in 8 hours. The speed of the engine varied from 150 to 250 revolutions per minute, while that of the drill varied from 75 to 125 revolutions per minute. The ignition in the cylinder of the engine was obtained by an electric spark from a bichromate battery, which served for about 500 hours. The speed of boring in the different strata, per shift of 8 hours with two men, was in sandstone 30 feet, shale 18 feet, ironstone 15 feet, and coal 47 feet. Better results could no doubt have been obtained, but the place where the drilling was carried on was very restricted, being at the bottom of a narrow shaft, necessitating the use of short lengths of rods, which entailed much waste of time in the frequent changing required. This method would, of course, not be suitable for workings producing fire-damp and where safety-lamps were used, for (unless the engine and battery were entirely enclosed) the ignition-spark would be sufficient to ignite an explosive atmosphere.

Mr. Robt. Martin (Portobello) wrote that he was somewhat interested in the subject of Mr. Wilson's paper, and he had recorded his own experience in the *Transactions*.* So far as he could judge, the only want or defect in the drilling apparatus was the absence of some means of washing or removing the drillings, which in most cases will cause much trouble. This can be readily effected by using hollow boring-rods, and forcing water through them to the point of the drill by means of a small hand-pump. The drilling-machine will then be much more easily driven, and one man can perform more work than two.

The problem of tapping old wastes is much simplified when the locality, pressure and quantity of water are known. In his (Mr. Martin's) own case, the wastes of three seams were over 100 years old. The plans and reports were most meagre, contradictory and obscure. In order to develop the colliery it was necessary to open a large number of faces (stoop-and-room), and that none of them should hole into the old workings. This was done by driving the rooms, 8 feet wide, with a sufficient number of bore-holes in front and flank, much farther ahead than was required by statute.

* *Trans. Inst. M.E.*, 1900, vol. xix., page 69.

The absence or presence of water in the coal-seam is most deceptive. In his (Mr. Martin's) own case there was a rush of water, and pressure at first on the miner's shot-holes of 13½ pounds per square inch, and they did not strike any old waste. At another colliery, in the west of Scotland, the workings which were very wet, gradually became quite dry as they approached an old colliery-waste with a large head of water.

Mr. W. B. Wilson, jun., replying to the discussion, wrote that the object of the Burnside safety boring apparatus is, to maintain convenient control over the water or gas when tapped, and not to assist in boring the holes. It can be, and has been used at some collieries with hollow bore-rods, as suggested, although he could not say what method was adopted of forcing water through the rods. The machines, described by Mr. R. Broom and Mr. G. L. Kerr, if used alone, make no provision for controlling the water or gas when tapped. The forcing of water, through bore-rods into a hole, which is being bored with the object of proving the absence or presence of water, conceals the first indications of its presence, and is, therefore, in his (Mr. Wilson's) opinion inadvisable, especially when used without any means of controlling the flow of water. At Wheatley Hill colliery, provision was made for the removal of the débris from the bore-holes, by using rods, with a double helical web running round the stem (Fig. 5, Plate IV.). The rods were frequently drawn out of the hole, and one withdrawal usually cleared the hole of all *débris*.

The usual method of wedging a pipe and tap into an enlargement of a bore-hole, was used at Wheatley Hill colliery on April 1st, 1901, when the pressure of water had diminished to 20 pounds per square inch. Mr. Henry Nisbet used a similar method at Devon colliery when boring against a waste, which contained water at a much greater pressure.*

The Burnside safety apparatus can be used as soon as the hole attains a length of 4 feet, although it is desirable to bore a longer length before enlarging the hole in order to fix the apparatus, as there is then more probability of the hole travelling in the intended direction.

The difficulty of restraining the holes from entering the roof was not due to the use of the Burnside apparatus, as the same

* *Trans. M.I. Scot.*, 1891, vol. xiii., pages 82 and 191.

difficulty existed when that apparatus was not used, and the stand of the drilling-machine (Figs. 4 and 5, Plate IV.) was fixed 2½ feet from the coal-face. The bore-holes, even when set away inclined downwards towards the bottom of the seam, took the form of a continuous curve, concave side upwards, through the full length of the hole.

He (Mr. Wilson) might mention that, with the exception of the piston-rod, R, (Figs. 4 and 5, Plate IV.) the bore-rods formed no portion of the Burnside safety apparatus.

It appeared to him (Mr. Wilson) that holes running so truely as those recorded by Mr. J. T. Forgie and Mr. Jas. Bain* must be due to some peculiarities in the lamination of the strata in which the boring was made, as it would be practically impossible to set a drilling-machine with sufficient accuracy to drill so true, even supposing the measures lay at an invariable inclination, which is improbable.

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## DISCUSSION OF PROF. H. LOUIS' PAPER ON THE "STANDARDIZATION OF SURVEYOR'S CHAINS."†

Mr. E. H. LIVEING (London) wrote that the facts and figures contained in Prof. Louis' interesting paper should be very useful to surveyors who desired to carry out accurate surveying. He fully concurred with the statement that the ordinary surveyor's chain was only suitable for rough work, such as filling in surveys. Personally he never used a chain for accurate work. He did not think that stretching or the opening of the joints were the only causes of increase of length with use, for he had found that even with brazed links of stout wire, a chain would increase in length, ¼ to ⅓ inch, in a long survey, over wet and muddy roads. There were about 600 bearing-surfaces in the links of a common chain which were always grinding together, and if it were assumed that the grit and water removed only $\frac{1}{1800}$ inch at each surface it would more than account for the elongation.

In using the ordinary steel tape for exact underground work he had found it convenient to stretch a wire or small cord from point to point, with sufficient strain to be practically straight, sup-

* *Trans. Inst. M.E.*, vol. xx., page 153.

† *Ibid.*, 1902, vol. xxiii., page 85.

ports being given at intervals if the span were long. The tape was then stretched, and allowed to rest on the top of the wire or cord, and its end carefully marked either by a pen and ink or a small screw-clip. The commencement and termination of each set of the survey were, of course, plumb-lines hung from plugs fixed in the roof, the cord or wire being stretched close to these without quite touching them.

Mr. R. F. PERCY (Nottingham) wrote that Prof. Louis had not exaggerated the difficulties of measuring underground lines of survey, and by determining the coefficients of elongation and shortening of the steel tape and chain when subjected to variations of temperature, tension and sag, he had supplied facts which would remove many hazy ideas. He (Mr. Percy) learnt long ago by experience that it was more difficult to measure lengths correctly than it was to measure angles, and that no reliance must ever be placed on assistants who had not been specially instructed and trained to the work. Similar difficulties and doubts arose in office practice, and the question, how far ivory and wooden scales could be trusted, was one of similar importance.

He had two steel tapes both supposed to be "standards," though they differed about $\frac{1}{2}$ inch in length. To ascertain the extent of error of these tapes he had found the method of comparison of tape and scale to be sufficiently effective for practical purposes. It was obvious that if the tape or chain was a proper and exact multiple of the divided scale used, the necessity of standardization was to a certain extent avoided. For this purpose he used a tested surveyor's wooden scale, 2 feet long. Upon a drawing-office table, pieces of paper were pasted 2 feet apart and a 10 feet straight line was drawn across them; and by means of the 2 feet scale, a fine pricker and a magnifying glass, a 10 feet length was laid down. This length was next by suitable means transferred to the tape, and repeated until the full length of 66 feet was marked out. If the work was done with great care, the 10 feet length laid down on the table ought to be within $\frac{1}{50}$ inch of the true length, and it was unlikely that the total error in the entire 66 feet length would exceed $\frac{1}{8}$ inch. This might appear a clumsy method, and it might be thought that the doubtful result would not repay the trouble; but it was certainly worth while for the surveyor to adopt it, if no reliable standard could be referred to. It should

be remembered that the probable extent of error was trivial, when compared with the mistakes which occurred almost invariably and unavoidably in the process of chaining in the mine.

It would be a great advantage to surveyors, if standards were laid down in all large towns, so that steel tapes and chains could be readily adjusted, and Prof. Louis deserved our thanks for his assistance in this direction.

Mr. HENRY JEPSON (Durham) wrote that if any surveyors in the neighbourhood of Durham found any difficulty in making a suitable standard of their own nearer home, he might mention that they would find one of a length of 66 feet on the pavement on the north side of the Palace Green, Durham. This was used many years ago by the late Mr. Arthur Beanlands, and was checked and marked more distinctly by himself (Mr. Jepson) about 20 years ago.

There were several practical reasons for preferring a steel tape to any chain on most occasions, especially underground, where the overlapping of the small links might pass unobserved. As a rule too, the light at the front end was reflected by the tape for most of its length, thus showing its position. From its lightness, it could easily be lifted bodily off the ground and laid in the line intended. For the same reason a moderate pull practically obviated error from sagging, which over ploughed land or fallen roads must be considerable where a chain is used. Steel tapes, however, compared with chains, required to be handled with a certain amount of care, kinking must be avoided, and a sharp jerk was liable to snap off a handle at the rivetting. They should be well cleaned and oiled after use, as they rust very rapidly.

Mr. J. T. STOBBS (Stoke-upon-Trent) wrote that the practical limits within which the surveyor's chain might be relied upon in length-measurement, was one of the first matters brought under his notice in starting his mining career, and every mine with which he had been connected had a permanent standard of its own, set out with great care, by which the chains could be tested and adjusted if necessary. The amount of error creeping into measurements did not arise so much from the inexactness of the chain itself, as from other causes inseparable from the circumstances under which distances were measured. We must remember that these measurements were made in the darkness of the mine, which

entailed extra care in satisfying oneself that no links were kinked, and that the chain lay straight on the floor and was directed in a straight line between the points whose distance apart was to be measured. Combined with the prevailing darkness, the roughness of the ground traversed was very liable to introduce error, such as the bending of the long links in passing around awkward corners of stone; the abnormal stretching of a (short) link due to a sudden stoppage of motion by a link catching under a rail, on a nail-head, or under a heavy stone, etc. Further, there was the source of error incidental to the system of marking the end of each chain-length, due to the width of the chalk-line or other distinctive mark. These difficulties were inherent in the work of measuring underground, whenever it was done on the floor, and in their presence it seemed to him that to speak of an error of 0·06 inch in the length of a standard chain was over-refinement.

The most important and difficult operation—the actual adjustment of chains—was not discussed by Prof. Louis, and he thought that a few remarks on that subject could not fail to be of practical value. This adjustment was generally performed by the foreman-blacksmith, and the accuracy with which this might be done was certainly commensurable with the exactness practicable in mensuration in a mine.

With reference to the use of steel tapes recommended by Prof. Louis, the only conditions under which they could be used with advantage over the chain, was where it was impossible to measure on the floor. The tape was certain to require much longer time for the work, and the figures marked on the tape would be more difficult to discern—especially as the tape became worn. This in itself promoted the commonest of all errors, namely, errors of observation. He must, therefore, take exception to the statement that steel tapes should be used wherever theodolites are used. He had known instances where, from surveys made by theodolite and chain, difficult holings had been made exact to 1 inch, between shafts 2, 3 and 4 miles apart, and he was of the opinion that such accuracy would satisfy any mining-engineer, but in order to obtain such results it was necessary to have the skill that only comes of practice, and unrelaxing care.

Prof. G. R. Thompson (Yorkshire College, Leeds) wrote that a constant measure was necessary when the surveyor had to make

surveys at different times and a standard measure when areas, etc., had to be fixed. The constant measure must be tested against variation, so for convenience in this case we also use a standard measure which can be accurately reproduced. If the surveyor used a chain which was 2 inches too long, or $\frac{1}{600}$th, the area determined would be $\frac{1}{300}$th too small, due to error, and a royalty of 600 acres would lose 2 acres. In chain-surveying, the error is usually estimated as 1 part in 1,000 over good ground, but over sloping ground with the method of stepping it becomes $\frac{1}{500}$th or even more. The same also applied when chaining on the slope, unless the slope of each chained length is accurately determined and the necessary correction applied. Assuming that $\frac{1}{1000}$th is the error incidental to ordinary chaining the error in acreage would be $\frac{1}{500}$th due to this cause; a chain tested to $\frac{1}{2}$ inch in 100 feet would add or substract $\frac{2}{3}$th as large an error; and one tested to $\frac{1}{4}$ inch would add or substract only $\frac{1}{9}$th as large an error. For ordinary work, we need therefore only test to say $\frac{1}{4}$ inch in an 100 feet chain, which could be done roughly at the mine or in any open place by laying down a standard from a new chain or surveying-band. But between this degree of accuracy and that required for the measurement of a geodetic base-line there is a vast gap. For example, suppose that we wish to measure our lengths for a traverse or for the base-line of a small triangulation survey with accuracy, comparable to an angular error of 30 seconds or to 1 part in 7,200, our chain must have a much smaller error or at $\frac{1}{3}$th say $\frac{1}{3600}$th or $\frac{1}{30}$th inch in 100 feet. It was for such work as this that the covered standard installed by Prof. Louis was of particular value. Perhaps the following experience would emphasize the point. Last June, wishing to determine the base-line of a small triangulation survey, with a 5 inches theodolite with such accuracy as the above, his students compared the 66 feet steelband with the municipal standard in George Square, Glasgow. The day on which this was first attempted was cool, with light winds and drifting clouds which gave fitful gleams of sunshine. Under these conditions, which might easily have been worse, it was found that the thermometers only indicated a change of 4° Fahr., while the steelband (assuming that it took the temperature of the thermometer when clouded) increased 20° Fahr. in temperature when exposed to the sun, the temperature of the band being estimated from the measured expansion. The uncorrected

temperature would introduce an error of $\frac{1}{10000}$th, which showed the necessity of testing the chain in the shade and of using it at the surface only under steady conditions.

There was a clerical error in giving the extension as 0·08 per cent. for a pull of 1 pound* instead of for a pull of 100 pounds, or 0·0008 per cent. for a pull of 1 pound.

Prof. Louis did well to call attention to the great permanent elongation of chains which usually took place, and to the imperfect method of adjusting such an extended chain, as recorded for chain I, which the screwed central compensating link (mentioned by Mr. Brough) did not overcome. Using chain I, which was only 0·75 inch too long, an error of 3 inches would be made in 166 feet and an error of 1·5 inches in 134 feet. The clearness of the graduations and general suitability for taking in surface-detail probably was the chief reason for the use of the chain; while underground the fact that rough usage only made the chain sick—very sick sometimes—and not dead for the time being was probably the most that could be said in its favour, and so he thought that Prof. Louis was fully justified in his conclusion.

Regarding the use of steel wires for accurate work mentioned in the discussion, he had long used galvanized-iron wire in 900 feet lengths for measuring traverse-lines with theodolite, whipping cord round the wire to indicate the different lines, and measuring each against the level standard. Failing a long steel-band this was a very accurate method. The objection to all wire methods of measuring was that unless kept taut the round wire fell into coils and on straightening the coils kinks occurred and the wire broke. This objection was not shared by flattened steel-bands. In measuring with wire, he used light, tripod supporting-stands to break the span of the wire so that W ÷ T = 1 ÷ 10 or nearly that. The tension was 10 pounds, measured by a spring-balance. He found that T could be easily measured to plus or minus 1 pound, which would introduce an error in the sag-correction of $\frac{1}{14000}$th or $\frac{1}{10000}$th respectively of the total length. The correction for sag in chaining, by stepping, could not be applied in practice when W ÷ T = 0·5, in this case an error of tension of 1·7 pounds in 16 would alter the correction by nearly 0·5 per cent. of the total length, and he was certain that difficulty would

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 87.

be experienced in getting men to judge this tension. His experience with 50 feet spans and station pole-rests was that the end of the chain could not be held very steady, and that in addition plumbing rendered accuracy impossible under normal atmospheric conditions at the surface.

Mr. HAROLD TARBUCK (Ryhope Colliery) wrote that whilst acknowledging the great benefit which Prof. Louis had accorded to surveyors by placing at their disposal an accurate standard chain-length at the Durham College of Science, in his opinion there was one drawback, and that was the time necessarily occupied in travelling to and from the college, by those residing at a distance, in order to make their periodical chain-tests. He thought that every colliery should have (and many have) accurate standards of their own, and he suggested the advisability of using the one at the college as a check on those that are laid down. With this object he ventured to describe to the members the method which he had adopted during the past 18 years in connection with various royalty and surface-surveys of which he had had charge. The instruments that he recommended were:—Two steel bars, each 5½ feet long, 1½ inches wide and having a thickness of ⅜ inch, one side of the bars being chamfered down from the full thickness to $\frac{1}{16}$ inch in a distance of ¾ inch (Figs. 1 and 2, Plate XIII.). One of the bars is marked with inches and tenths, and the other one is unmarked, but of the same length of 5½ feet, and each bar is fitted with 2 brass knobs or handles on the upper surface, to facilitate the removal of the bars, when in use during the marking out of a standard chain-length. The standard steel bars (Figs. 1 and 2, Plate XIII.) were made by Sir Joseph Whitworth & Sons, Manchester, and, having been tested and retested, are absolutely correct at 62° Fahr.

The method of marking out a standard chain-length is as follows:—On level ground, preferably under cover, place five stones, *a*, each 1 foot deep, 10 inches thick, and 10 inches wide, fitted with square brass-plates, *b*, at the centre and on the top of each stone, fastened into position, by means of melted lead, at the respective lengths of 0, 25, 50, 75 and 100 links. Cement-concrete, *c*, 6 inches thick and 10 inches wide (though not absolutely requisite) fills the space between each of the stones, with the exception of 1 inch, at each side, and this cavity is afterwards filled with

well puddled clay, *d*. Oaken planks, *e*, 4 inches wide and 1 inch thick, are embedded in position in the concrete, with their ends abutting on, but ½ inch short of, each stone. At the centre of the first plate, a clear cut is marked for zero, and from the centre of it a line is run across the other plates and over the oaken planks to the end one, in order that the lengths may be measured in a straight line.

One end of a steel standard-bar is applied to the mark on the first plate, the bar itself being laid along the marked line; and, leaving it fixed firmly in that position, the other bar is applied to the first one, with the adjacent ends perfectly flush with each other, and when the second bar is fixed in position, the first one is removed and the process is repeated, the different lengths being marked with a needle pointer at the end of 3, 6, 9 and 12 bar-measurements.

TABLE I.—LENGTHS OF SCALES.

| No. | Maker. | Description of Scale | Length of Scale. | Error in a Length of Scale. | Error per Mile. |
|---|---|---|---|---|---|
| | | | Inches. | | |
| 1 | A | 6 chains to 1 inch. | 12 | Nil. | Nil. |
| 2 | A | 1 chain to 1 inch. | 12 | 1 link short at 12 chains. | 6·66 links. |
| 3 | A | 22 yards to 1 inch. | 12 | 0·5 yard short at 22 chains. | 1·82 yards. |
| 4 | A | 22 yards to 1 inch. | 12 | 0·4 yard short at 22 chains. | 1·45 yards. |
| 5 | A | 32 yards to 1 inch. | 11·87 | 0·5 yard short at 32 chains. | 1·25 yards. |
| 6 | A | 2 chains to 1 inch. | 12 | 3 links short at 24 chains. | 10·00 links. |
| 7 | B | 3 chains to 1 inch. | 12 | 5 links short at 36 chains. | 11·11 links. |
| 8 | C | 3 chains to 1 inch. | 12 | 6 links short at 36 chains | 13·33 links. |
| 9 | D | 3 chains to 1 inch. | 12 | 5 links short at 36 chains. | 11·11 links. |
| 10 | D | 3 chains to 1 inch. | 12 | 2 links short at 36 chains. | 4·44 links. |

The British standard temperature being 62° Fahr. if difficulty is experienced in obtaining a regular temperature of that amount, the difference due either to contraction or expansion can be adjusted by means of a micrometer, using the figures mentioned in Prof. Louis' paper, namely:—0·005 inch for every increase or decrease of temperature of 1° Fahr. for 66 feet.

The standard bar may be applied to other important uses:—
(1) Testing scales, and the correctness of a scale is of as great

To illustrate Mr. Harold Tarbuck's Notes on the "Standardization of Surveyors' Chains."

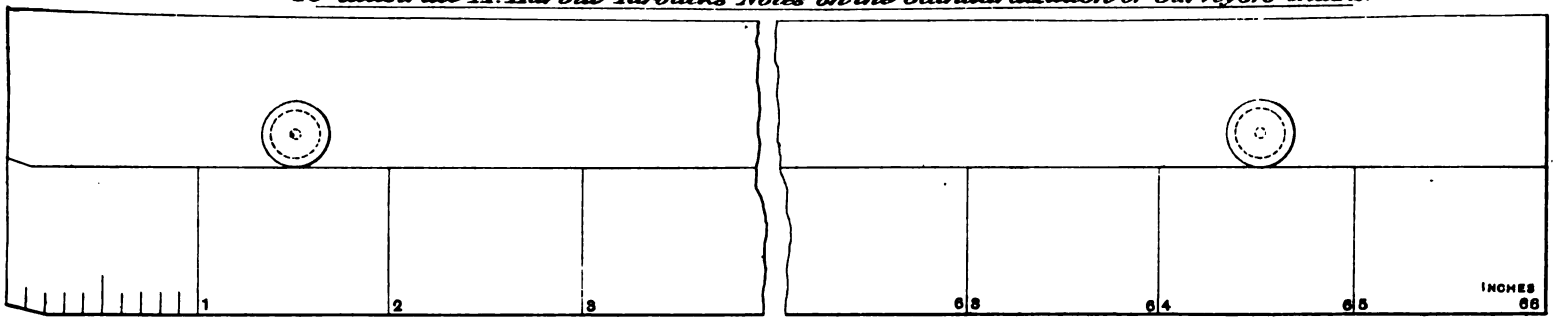


FIG. 1.—PLAN OF STANDARD STEEL BAR.

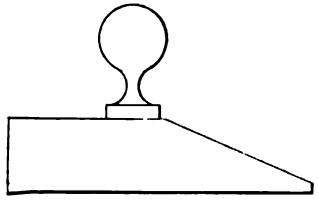

FIG. 2.—CROSS-SECTION OF FIG. 1.

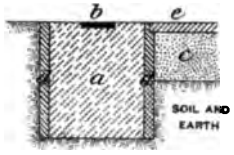


FIG. 4.—SIDE ELEVATION.

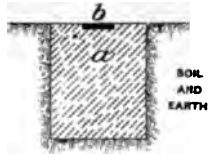


FIG. 5.—CROSS-SECTION ON LINE A B OF FIG. 3.

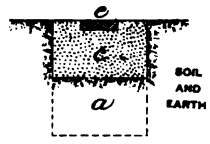


FIG. 6.—CROSS-SECTION ON LINE C D OF FIG. 3.

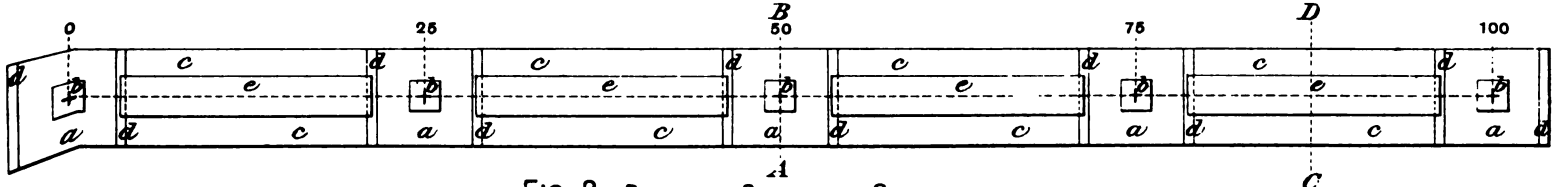


FIG. 3.—PLAN OF STANDARD CHAIN-LENGTH.

Scale, 20 Inches to 1 Inch.



And.r Reid & Comp.y L.td Newcastle on Tyne.

importance as the possession of a chain of correct length. He (Mr. Tarbuck) had tested several ivory scales made by different makers, and on comparing them with the standard bar, he had obtained the results recorded in Table I. (2) To mark accurately permanent lengths of 20 chains (or other distances) both in longitudinal and transverse directions on mounted drawing-paper, previous to plotting any survey thereon, and thereafter, at any time, the amount of contraction of the paper—which of course affects the position of the estate-boundaries, and consequently the amount of royalty-rent due to each respective owner—may be accurately ascertained.

Among other advantages gained by using standard steel-bars as compared with steel-tapes, when marking chain or other lengths might be mentioned:—(1) A more correct measurement, and less time occupied in obtaining it; (2) the errors due to the effects of pull and of sag are entirely removed; (3) the standard bars can be used with advantage for other important purposes in the standardization of lengths, such as scale-tests, or ascertainment of errors due to contraction or expansion of plan-paper; and (4) they afford ready facilities for daily chain-tests, when engaged on large surveys away from home, or abroad, and especially for those engaged in railway-work.

Prof. H. Louis (Durham College of Science) wrote that he was greatly obliged to the members who had taken part in the discussion, and was gratified to find that the general concensus of opinion was in support of the views he had expressed. Mr. Stobbs seemed to be quite alone in not preferring the steel tape to the chain, when especially accurate work was required. He was obliged to Prof. Thompson for calling attention to the omission of the words "for a pull of 100 pounds" after the word "per cent."* in his paper. Mr. Percy's method of standardising, by means of a scale, should be an accurate one, but he, for his part, preferred to use specially made trammels, very carefully set. There was also very much to be said for Mr. Tarbuck's method of employing bars. This latter method had been brought to a high state of perfection in Germany, where bars were used with both ends chisel-shaped, the two edges being perpendicular to each other; such bars are at times made composite, so as either to compensate

* *Trans. Inst. M.E.*, vol. xxiii., page 87, line 14.

for changes of temperature, or else to enable such changes to be accurately determined. For a description of these he would refer to the wellknown work *Elemente der Vermessungskunde*, by Mr. Max. v. Bauernfeind.* He hoped that surveyors would adopt Mr. Tarbuck's suggestion, and use the standard chain-length at the college to check those laid down at the collieries of the district, and in order to make it more useful, he had adopted the suggestion made by Mr. Leach and the President, and had set out a mark at every tenth link.

Personally he did not hold with Messrs. Percy and Tarbuck that the accuracy of scales was as important as that of chains, because he never trusted his plans except for the very roughest calculations. He did all his work entirely by co-ordinates, upon the methods and for the reasons given in his recently published little book.† His practice for many years past had been to calculate the co-ordinates of all the important points upon mining properties under his charge, to record these in tabular form, and to use these co-ordinates and not the plans for calculating areas, etc. He could strongly recommend this method on the score of both accuracy and speed; obviously by its use errors in plotting (due to inexact scales, carelessness, shrinkage of paper, etc.) were rendered harmless, and any desired degree of accuracy could be attained.

Mr. JOHN M. LIDDELL (Newcastle-upon-Tyne), as to the provision for fixing and preserving test-marks, wrote that there was only one desirable method, namely, that of marking the walls of substantial stone buildings. These marks should be placed upon the walls or close to the walls and at the level of the floor or of a solid ledge of masonry, so that the chain may be borne level and straight throughout its length; the marks should indicate the positions of all the links of the chain as well as the tens and the ends of the chain, and should have attached a note of the limits of temperature within which steel chains, etc., should agree with the said marks. Anyone, testing a chain, could then place it in position and at once perceive an error, the point at which it occurred, and also what corrections were required. Metallic standards were of course unsuitable. Wooden rods had been used

* 1890, vol. i., page 382.

† *Traverse Tables*, with an introductory chapter on Co-ordinate Surveying, by Prof. H. Louis, and Mr. G. W. Caunt, 1901.

in South Africa for testing in the field, but such pairs of rods (about 7 feet long if he recollected rightly) were difficult to apply accurately, and, as some kinds of wood expanded and contracted longitudinally, he also thought that wood was undesirable. Two marks in a stone passage in the Government Buildings at Cape Town were used for a chain-test, and he thought that there was no reason to doubt the permanence of marks upon a substantial stone basement. For business purposes, in addition to the standard lengths laid down by Prof. Louis at the Durham College of Science, he suggested that marks might reasonably be placed on one of the walls of the Institute building, the Town Hall, St. Nicholas' Cathedral, or any safe building that is convenient of access, and that they should be tested and stamped by an official of the Board of Trade for public or private use. Similar marks should also be placed throughout the district at suitable centres, as, unless they can be reached without a troublesome journey, they will often be neglected when they ought to be taken advantage of.

He (Mr. Liddell) could not understand why measures of length are not as much liable to inspection and correction as measures of weight and capacity by officials of the Board of Trade, and the advantages to a surveyor of keeping chains of accurate length as against correcting the results of inaccuracy compiled in old pit plans are immeasurable.

Mr. H. D. Hoskold (Buenos Ayres) wrote that those who have had much practice in surveying for the object of forming accurate maps and in carrying out railway and other classes of extensive public works, as also, underground, in mines, are fully aware that correctly observed angles would be worthless unless equal accuracy could be insured in the measurement of the various lines which would of necessity enter into any such operations. Prof. Louis had, therefore, rendered great service to mining-engineers in advancing this important subject, and it is to be hoped that every surveyor in his district will take advantage of the plan initiated, to compare and correct their measuring chains.

He (Mr. Hoskold) had already indicated* the great amount of accuracy which had already been achieved in measuring base-lines for various national trigonometrical and other surveys, as also of the class and comparative excellence of the linear measuring-instruments employed.

* *Trans. Inst. M.E.*, 1900, vol. xix., pages 189 to 200.

Measuring-chains are generally constructed of iron wire, sometimes galvanized, as also of steel wire. The ordinary or common measuring-chains, generally adopted, are subject to the errors pointed out by Prof. Louis, and after considerable use are frequently found to be too long, producing proportional error in the measured distance. It is evident, therefore, that some facile means of correction is necessary and should be always ready at hand for reference. Standards should, consequently, exist in every mining district, similar to that introduced by Prof. Louis, by which measuring-chains could readily be tested.

Besides the errors indicated in the paper to which surveyor's common measuring-chains are constantly liable, there exist, also, others of a more temporary nature, equally vitiating, that is, it frequently happens that the longer links of a chain are bent or shortened by being carelessly trodden upon by the chainmen; and also when the chain is drawn through hedges, damp grass-fields, along dirty and muddy turnpike-roads, and many other similar places in damp weather, and in dirty and wet roads in mines, the shorter, round, connecting links, generally three in number, joining the longer ones, are liable to be filled with wet débris, producing what is commonly called kinking or twisting, and so forming knots in the short links, and this may occur at several points in the chain at the same time, and so shorten it to a considerable extent. If the surveyor be vigilant and takes the trouble to superintend the measurement of the lines himself (which he should do) such a shortening of the chain as that indicated would not be likely to escape attention so easily upon the surface, as it would underground, where there is less room and light to manipulate. Chainmen may be well trained to measure a given line backwards and forwards several times with but little or no error, still, we know that towards the end of a long and laborious days' work, they become tired and careless, and do not possess the same interest in the result of the survey as the surveyor himself, consequently, if they have no special superintendence on the part of the surveyor, or some other equally qualified person, such apparently slight but continuous repeated errors due to kinking, would not appear to them of any consequence, and so be allowed to pass. When therefore, an underground survey of great importance is undertaken for the object of forming an accurate plan of the workings in reference to boundary-lines dividing various properties, and other objects, or for that of driving any long and

expensive tunnel or heading from two opposite points, then the surveyor should not only be careful about the extreme accuracy of his angles; but the measurement of each of the lines as well. Although a given chain may have been tested by a standard, its use in the cases cited and for other important work, should never be trusted indiscriminately to chainmen.

The rough usage to which an ordinary measuring-chain is constantly subjected renders elongation of the three small, round, connecting links inevitable: but in the best chains, that is, standard chains, made of steel wire, the joints are brazed, which prevents them from opening when great strain is put upon the chain; but it does not prevent their change from a round to an elongated or oval form, due to a constant practice of jerking or applying too much pulling force, which is a general practice of chainmen. The apparent cure for this defect would be to construct a chain with the shorter connecting links fewer in number, say, for example, one or two in place of three, making them of an elongated oval form; the joints being always brazed. He (Mr. Hoskold) was, however, of opinion that the perfect chain of the future has to be invented and constructed.

Probably the best way to overcome the elongation of the shorter links in a chain, and the errors due to them, including that of kinking, would be to reduce the number of the smaller connecting links, say from three to a single one, making it longer than at present, brazing the joints, and constructing the longer links forming the body of the chain two or three times the length of the present ones, and so reduce all the common errors indicated in the same proportion. Besides, it may not be altogether impossible to construct chains in this way of larger wire drawn from some well-tried metallic alloy, which may give a greater resistance to the pulling force, and also be as light or lighter in weight than the ordinary constructed chains.

In order to correct measuring-chains, some surveyors adopt the plan of driving two stout wooden pegs into the ground, 66 feet apart, from centre to centre, and applying the measuring-chain to it when necessary and when the chain is found too long, some of the shorter links are removed, in order to reduce the chain to a proper length; but this practice is not commendable. When the chain is too short all the links are examined and straightened, and if still in defect, the difference is allowed for upon the length of each line.

Many years ago, he (Mr. Hoskold) adopted the plan of selecting a level place and letting into the ground, to a depth of 3 feet, two properly prepared stones, 12 inches square in section, and 66 feet apart from the centre of one to that of the other. A copper plug, 1 inch in diameter, was let into each of the stones, and a small centre mark made in each. The distance between these marks was set out by as correct a measuring-tape as could be procured, and then the process was repeated with a 16 feet levelling-staff. The distance was finally checked with a 6 feet steel standard-bar, 1 inch square in section, specially constructed by Messrs. Troughton and Simms, London. When it was discovered that 11 lengths of the standard-bar fell short of, or over-reached, the dot placed in the copper plug at the second stone station, a proper adjustment was made until eleven lengths of the steel bar measured the line of 66 feet between the dots in the copper plugs. This steel bar was carefully kept in a box free from great changes of heat or cold. When these stone stations were covered over so as to prevent as much as possible the effects due to heat and cold, fairly good results were obtained when chains were compared. Considering, however, that the effects of expansion and contraction due to heat and cold, in this special case, were not at that period determined, the plan could not be compared with the more accurate and scientific one now introduced by Prof. Louis.

Instead of a measuring-chain being "so safe, in unpracticed hands,"* as Mr. Bennett H. Brough asserted, we know, that experience proves just the contrary, in fact, we may safely conclude that nothing of importance and requiring accuracy would be "safe in unpracticed hands," and he (Mr. Hoskold) fully agreed with Prof. Louis in his *dictum* on this point.

When conducting such surveying operations as were necessary to assist in the construction of the large topographical map of the Argentine Republic, which he (Mr. Hoskold) published in London, he had sufficient evidence to show how far the measurements of the various lines could be trusted "to unpracticed hands."

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Mr. EDWARD HALSE's paper on "Some Silver-bearing Veins of Mexico" was read as follows:—†

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 92.

† This paper was read at a general meeting held on December 14th, 1901.

# SOME SILVER-BEARING VEINS OF MEXICO.

(*Continued.**)

By EDWARD HALSE.

## Santa Cruz de Alaya, State of Sinaloa.

The small town of Santa Cruz de Alayá, some 60 miles north of the Pacific port of Mazatlan, is situated on a range of hills forming a part of the western flank of the Sierra Madre, which, in this portion of the Republic, trends north-west and south-east. Here, a considerable outcrop of calcareous rock is seen, most probably of Cretaceous age, which hitherto would appear to have been overlooked, as it is not marked in Dr. F. G. Weidner's geological map of Sinaloa.†

The town of Santa Cruz is between 200 and 300 feet‡ above sea-level, and the surrounding hills are at an elevation of from 500 to 1,300 feet. The hills and cañadas are more or less covered with bush, which is almost leafless in the dry season, but bursts into a dense mass of vegetation soon after the rains have set in. In the dry season, the temperature at night ranges from 75° to 85° Fahr. rising to 97° Fahr. in the shade for some hours in the middle of the day. The average temperature at this season of the year is about 10° Fahr. higher than that of Mazatlan, nevertheless the climate is a fairly healthy one.

A number of silver-bearing veins course through the limestone-country near Santa Cruz, but, as the ore is refractory and can probably be treated satisfactorily only by the sodium-hyposulphite process on a large scale, which necessarily implies the outlay of considerable capital, the developments up to date have been small in extent, the owners of the various properties contenting themselves with raising only high-grade ore for exportation, or with

* *Trans. Inst. M.E.*, 1900, vol. xviii., page 370; 1901, vol. xxi., page 198.

† *Der Staat Sinaloa in Mexiko*, 1 in 1,500,000, Gotha, Justus Perthes, 1884. This map is incorporated in the geological sketch-map of Mexico, published by the Geological Institute, for which reason the latter also shows no Cretaceous rocks in this area.

‡ The heights given in this paper were taken with a small pocket-aneroid barometer, and are therefore only roughly approximate.

holding on to the mines in the expectation of a rise in the price of the white metal.

At Santa Cruz, and for some distance to the south of it, limestone-rock predominates. Starting from the *hacienda*, a little north of the village, and proceeding in a northerly direction along the banks of the Quilá stream, the following rocks are met with, in the order named:—Red clay with boulders, conglomerates, shale-beds (strike west 22½ degrees north to east 22½ degrees south,* dip southward 14 degrees to 18 degrees), thin purple shales (dip southward 25 degrees), beds from 1 to 2 feet thick of dark-stained grit or quartzite of fine texture (dip south 25 degrees, the main joints of this rock dip northward 84 degrees), purple shales, conglomerate, a considerable thickness of green and yellow arenaceous shales (strike east 40 degrees south, the main joints course north 10 degrees east, and dip westward 41 degrees), similar beds striking north 40 degrees west (the main joints also form an angle of 60 degrees with the line of bedding and dip westward 43 to 46 degrees), a thick deposit of purple conglomerate or breccia (apparently basaltic), and limestone-country proper. The latter was no doubt at one time continuous, and formed an anticlinal with similar rock at Santa Cruz.

The limestone is either homogeneous, or, more frequently, exhibits a number of thin bands of hard siliceous matter (chert), which give the rock a coarsely ribbon-like structure. Here and there are intercalations of what appears to be schistose rock. The limestone is at least 2,000 feet thick, and can be traced to within a few miles of Cosalá, in places forming high bluffs. The layers dip in a northerly direction, or contrary to the schistose rocks and grits farther south. The writer believes that the limestone belongs to the Middle Cretaceous,† while the remaining beds are of Lower Cretaceous or possibly of Jurassic age.

The Middle Cretaceous formation of Mexico has suffered far more dislocations than the other divisions of the same group, owing to the orogenic movements which determined the uplift of nearly all the lines of relief, and the emersion of the whole superfices of Mexican territory from the Cretaceous seas.‡

* Directions are magnetic, unless otherwise stated: for variation see Fig. 1, Plate XIV.

† From its resemblance to limestone of this age in other parts of Mexico. See *Boletin del Instituto Geológico de México*, Nos. 4, 5 and 6, pages 211 and 212.

‡ *Ibid.*, page 212.

The limestone-beds of Santa Cruz, speaking generally, strike in a north-westerly and south-easterly direction, and dip north-eastward. Locally the trend may be within a few degrees of east-and-west, or even up to 45 degrees north of east and south of west, the dip being to the north, and only occasionally in a contrary direction.

The principal veins strike through the limestone in a general northerly and southerly (true) direction; sometimes the veins course with the country-rock, more frequently they form acute angles with it, and sometimes they strike right across the bedding-planes.

Durango City is situated 100 miles from the port of Mazatlan on a line directed north 26½ degrees east (true) from the latter. The city is on a plain, a little east of the Sierra Madre, but if we mark off on a map of Mexico two-thirds of the distance and run a line northwards from this point to El Altar, in the State of Sonora, such will represent for upwards of 600 miles the main axis* of this great range of mountains in the north-western portion of the republic. This axial line is directed north 37½ degrees west (true), so that the chief veins of the district now being described, form an angle of 37½ degrees, while other veins are roughly parallel with it. The north-and-south veins, however, are apt to bend round locally to north-north-west or north-west, while one vein (possibly a branch-vein) trends some degrees east of north. This will be seen by referring to Fig. 1 (Plate XIV.), which is a sketch-plan of a few of the veins of this district. The radiated appearance of the veins at and near the Santa Eduvigis mine is somewhat remarkable.

The north-and-south veins almost invariably dip in a westerly direction, or opposite to the dip of the beds of limestone. In the only instance observed where both country-rock and vein dip in the same direction, the actual dip of the former is less by several degrees than that of the latter (Fig. 5, Plate XIV.). This indicates that when the system of fractures or shear-planes was

* A glance at a map of Mexico will show that this axis is roughly parallel to the peninsula of Lower California as well as to the Gulf of California. The latter, no doubt, occupies a deep depression or crevasse between the two ranges of mountains, which are of contemporaneous origin. In reality, the three axes approach each other in a northerly direction, for the axis of Lower California is directed north 30 degrees west (true), and that of the Gulf of California is approximately north 31½ degrees west (true).

formed, which subsequently became mineralized, the lines of least resistance did not correspond with the bedding-planes.

Fig. 2 (Plate XIV.) represents a section of the Santa Eduvigis vein, coursing in a general north-westerly to south-easterly direction; the dip is south-westward 47 degrees, while the country-rock on the north-east wall dips north-eastward 36 degrees. The dark siliceous layers are traceable right up to the foot-wall side of the vein. The hanging-wall appears to be dark shaly carbonaceous limestone; the vein therefore would seem to occupy a line of fault. The occurrence of black limestone and shale is usually a sign of poverty in this district.

The country has been considerably disturbed here, for in one cross-cut the limestone-beds strike north-east and dip north-westward 42 degrees; in another cross-cut in the same workings the beds are seen to trend east-and-west and to dip northward 37 degrees. This would seem as if portions of the country had been bent round horizontally, without being turned over (the dip being always northerly). The foot-wall of one vein, a little south-west of this point, shows a number of lines (slickensides) which are almost horizontal, the dip being only a few degrees to the south. Another vein, a little north of the same point, strikes north 21 degrees east and dips westward 57½ to 64 degrees, or right across the beds of the country-rock, which in the northern face of the working, are seen dipping in an inbye direction, and the nearly horizontal slickensides of the foot-wall are seen to dip a few degrees outbye (or in a southerly direction). The ore of this vein is chiefly iron-pyrites with some galena, mispickel and blende in fine grains in yellow-stained quartz.

The above facts furnish further evidence of horizontal thrusting having taken place in the lodes and adjoining country.

The Santa Eduvigis vein, at the point examined (Fig. 2) has a width of 4½ feet; the ore, consisting of argentiferous blende with some iron and copper-pyrites and mispickel, with occasional spots or argentite and ruby-silver, in a matrix of quartz, calcite and some limestone, is confined to a layer from 1 to 2 feet thick on the foot-wall side. The rest of the vein consists of dark limestone veined with calcite in large crystals.

Fig. 3 (Plate XIV.) represents a north-north-west vein dipping south-south-westward 53 degrees. The cherty layers of the limestone are clearly seen right up to both walls, dipping north-north-

eastward 40 degrees. The ore, similar to the last, is here confined to two pay-streaks, that on the hanging-wall being 20 inches thick of calcite, quartz and sulphides. The foot-wall streak is only 6 inches thick. Between these bands lies ordinary country-rock, the ribbon-like structure of which has been obliterated. The streaks of ore show a tendency to come together below. Formerly some chloride of silver in small leaders (*hilos*) was extracted from the vein.

Fig. 4 (Plate XIV.) is a plan of the same vein where it cuts right across the country. It will be seen that while the vein dips in a westerly direction, the beds dip northward 36 degrees.

Fig. 5 (Plate XIV.) is a section of a vein striking north 41½ degrees west, and dipping 56 degrees in the same direction as the country-rock (the latter dips from 32 to 45 degrees). As in Fig. 2, the dark siliceous layers are visible only on the foot-wall side.

In one instance, where a vein coursing north 30 degrees west crosses the limestone almost at right angles to the planes of deposition, a horse of country-rock with cherty layers dipping northward 40 degrees is observed in the upper portion of the section (Fig. 6, Plate XIV.), clearly showing that the vein was not an open cavity, but was most probably produced by shearing. No doubt most of the veins of this district were produced in the same way, the country enclosed by the contiguous shear-planes having become more or less metamorphosed by the mineral solutions which have made their way up and along these.

The writer visited the district in 1891, again in 1892, and for a third time in 1895. On the last occasion, he had an opportunity of seeing under what conditions high-grade ore occurs. Fig. 7 (Plate XIV.) is a cross-section of the deposit. The vein strikes north-west and south-east, and dips south-westward 52 degrees. Some *gambucinos* working here, struck into high-grade ore and extracted it for a length of 10 feet. On the hanging-wall is a layer, 6 inches thick, of high-grade ore, similar to that already mentioned, but containing a greater proportion of argentite and ruby-silver. On the foot-wall side, separated from the hanging-wall by 4 feet 8 inches of limestone, lies a streak of lower grade or second-class ore, 4 inches in width. The ore from the hanging-wall streak, hand-picked, assayed as much as 1,120 ounces of silver per ton, that from the foot-wall side, also hand-picked, assayed 140 ounces to the ton. Cherty layers were visible in the

centre of the vein, and appeared to be continuous from hanging- to foot-wall, but the country-rock between the so-called walls was somewhat altered, and was impregnated with ore here and there. On cross-cutting in a north-easterly direction, 3 feet from the foot-wall, another streak of second-class ore, from 6 to 12 inches wide, was discovered. This would appear to be an instance of a compound replacement-vein which has been formed along three parallel shear-planes. It is worthy of note that the high-grade ore is not a continuous bunch or streak, but it comes in and goes out in wedge-like or lenticular masses, which may be from 10 inches to a few feet in length, and is succeeded by country-rock impregnated with ore. The high-grade streak was also found to change its position from one side of the vein to the other.

The "open-fissure" theory will certainly not apply here, as it fails to apply in so many examples of vein-structure in different regions of the world, and, although there is a roughly banded structure, the bands are neither continuous nor symmetrical, and there is no evidence of what Prof. Posepny terms "crusted rock-kernels" to show that even a portion of the lode was once an open space.

By the term "wall" is usually meant the bounding-plane of a lode, or the side of the original fissure, but some interesting examples of "walls within walls" and of "walls beyond walls" have recently been given by Mr. T. A. Rickard,* and anyone who has carefully examined the structure of ore-bearing veins can readily multiply examples for himself. The fact that outside the so-called "wall" of a lode other walls may occur, sometimes bearing payable ore, shows the necessity of frequent cross-cutting, especially from those veins which have a compound structure.

Hitherto the district has remained undeveloped, so that it is impossible to say whether the bunches or shoots of ore have a definite pitch in one direction of the strike, but as the main joints as well as the beds dip in a northerly direction, ore-shoots, if they have any pitch at all, are more likely to follow this than the reverse direction.

The filling of most of the veins referred to is of medium texture, occasionally exhibiting coarse crystals or crystalline patches of blende, galena, etc. Another class of vein, usually con-

* "Vein-walls," *Transactions of the American Institute of Mining Engineers*, 1896, vol. xxvi., page 193.

fined to the solid limestone, consists of very fine-grained argentiferous blende and mispickel, more or less scattered through country-rock. A typical vein of this class runs north-west and south-east, and dips from 56 degrees near the surface to 65 degrees at a depth of 55 feet, where the vein is from 3¼ to 4¼ feet in width. The best ore lies on the hanging-wall side, and is from 9 inches to 1 foot thick. Some chloride of silver in soft threads was formerly raised from here. The hanging-wall is well-defined, and with the ore occurs some blue and yellow quartz. From this streak to the foot-wall the filling is limestone, scattered with very finely-grained sulphides with some oxide of iron and calcite, a thin layer of the last-named mineral lies on the foot-wall.

Miners in most regions recognize good and bad indications of ore. In this district, a dry black coating of the colour of roasted coffee, termed *miche*,* is looked upon as an unfavourable sign, as well as certain kinds of metallic coatings termed *pasta*† (paste): those of a rounded appearance (*pasta china*), of a violet colour (*pasta morada*), or of a lead-coloured greasy appearance (*pasta mantecosa*) are disliked, while a black metallic coating (*pasta negra*) is regarded as a favourable indication.

Although rich patches of ore not infrequently occur, the average silver value of the veins is undoubtedly low, and they probably do not contain more than from 30 to 40 ounces to the ton, while the gold in the ore varies from traces up to 5 dwts. to the ton.

### Santiago Papasquiero and San Dimas, State of Durango.

About 100 miles north-west of Durango City in the district of Santiago Papasquiero, and crossing perpendicularly a deep valley, along the bottom of which flows the Quilá stream, already mentioned, is the outcrop of a silver-bearing vein forming a portion of a bold ridge, which, on the north side of the stream, attains an elevation of about 3,000 feet in a horizontal length of about 5,000

* At Fresnillo, State of Zacatecas, *miche* is a mixture of galena, blende, and pyrites, the two first being silver-bearing. It is not liked by the miners.

† In Mexico, *pasta* is the name generally given to argentiferous ores, as blende, galena, etc., not of high grade. At Ozamatlan, Michoacan, it is black sulphide of silver (argentite); in Chili and in Guerrero, Mexico, grey copper-ore (tetrahedrite) rich in silver; at Zacualpan, State of Mexico, silver-bearing iron-pyrites. The term *pasta* is sometimes given to bullion or uncoined silver. Mr. J. B. Guim gives "pedazo de oro de plata ó de otro metal, fundido y sin labrar," *Diccionario*, 1864. In Mexico, *plata mista* is silver bullion, and *plata pasta* is spongy silver after retorting.

feet. The upper third of this ridge is very steep (43 degrees) while the lower portion slopes towards the river at an angle of about 27 degrees. It is at and near where these two angles of slope meet that the principal workings are found. On either side of the ridge, the rocks have been eroded into deep *quebradas* or ravines, the average slope of which is some 9 degrees less than that of the ridge itself. This vein, although in the main of low-grade value, is remarkable for its width, variability in ore-contents and structure.

The rocks of the district consist of recent eruptives, quartz-hornblende-andesite, andesitic conglomerate or breccia, and porphyrite (a much altered type of andesite), with interbedded and intrusive dykes of felsite of the rhyolite group. Locally the country-rock is known as "porphyry" and "quartzite." The former name is usually restricted to more or less kaolinized felsite, and the latter to silicified felsite, or to normal felsite with flow-structure, the latter appearing as very thin brown, green and yellow layers, giving the rock a finely ribbon-like structure. Sometimes the rock is highly pyritous without the flow-structure being obliterated.

The vein courses in a general north-westerly to south-easterly direction, the dip being north-eastward about 65 degrees; the width varies considerably, and in some places is 50 feet and over. The veinstone is composed of quartz, calcite and altered country; the ore consists of argentite, with native gold and silver (at and near the surface), argentiferous iron-pyrites and some copper-pyrites, and with galena, chloride of silver (near the surface), and ruby-silver occasionally.

The ore is often composed of wavy black layers alternating with lighter ones, having a conchoidal texture, and is then known as *metal caracol*, while at other times it is recognizable only as black spots and discolorations.

The vein sometimes exhibits a conglomeratic or coarsely-brecciated structure, generally confined to one wall (Fig. 12, Plate XV.), or it may occur as a band nearer the centre of the vein (Fig. 18, Plate XV.). In places the vein, examined with a microscope, shows a true brecciated structure, but more often it is coarsely banded, seams of ore alternating with more or less altered country-rock.

The strike and dip vary a good deal locally, the former ranging

from north 34 degrees west to north 67½ degrees west, and the latter from 45 to 70 degrees. Here and there the walls are well-defined, and sometimes appear to be absent altogether. One or both walls may be marked by a clay gouge a few inches thick, and, as a rule, good ore generally occurs on this. Sometimes there is a foot or so of red clay on the foot-wall, containing loose pebbles of matrix, rock and ore (agglomeratic).

The outcrop of the vein on the right bank of the stream strikes north 50 degrees west and dips north-eastward 65 degrees, while on the left bank, a few feet lower down, the strike is north 30 degrees west and the dip the same, which shows that the vein has been dislocated and bent here. The vein on the right bank forms the foot-wall of a dyke of felsite. Fig. 8 (Plate XIV.) is a sketch-plan of the rocks as seen at this point. Six felsite-dykes are visible here separated by varying widths of andesite. The hanging-wall side of the dyke which carries the lode is not sharply defined from the purplish andesite, there is a passage between the two, patches of andesite are first seen, then alternate layers of andesite and felsite before the andesite proper is reached. This dyke would therefore appear to be interbedded.

The strike of the country-rock generally corresponds with that of the vein, but the dips are by no means always identical. There is a working some distance above the river where both vein and country strike north 34 degrees west, but the dips are 63 to 75 degrees and 33 degrees respectively; here the country-rock exhibits brown and yellow or green and white flow-structure, and in places the beds are highly pyritous.

On the summit of the hill, the vein courses north 37 degrees west, dips north-eastward 67 degrees, and appears to follow the strike of the country; but the beds of the latter dip 78 degrees in the opposite direction, and another vein, striking north 45 degrees east and dipping south-westward 80 degrees forms a junction with it. The surface-ores here contain calcite stained green by carbonate of copper (malachite), and contain some visible gold.

In the north-easterly to south-westerly veins, the shoots of ore have a tendency to pitch north-eastward at a high angle, following the dip of the cross-joints.

In the main vein, cross-joints, dipping in the opposite direction, appear to have a favourable influence on the vein-contents. Fig. 9 (Plate XIV.) is an instance observed in a working 1,875 feet

above the river. The vein runs north 20 degrees west, and, between two joints, trending east-and-west and dipping southward 80 degrees, the best ore is found. The joints are lined with red clay, which flakes off, and the ore is principally of the class known as *caracol*.

The joints are probably shear-planes which have been formed in a direction oblique to the vein itself, for the master-joints of the country-rock dip northward. These joints are sometimes lined with several inches of various coloured clays, as light yellow, bright ochre, flesh colour, chocolate or blue, and the parti-coloured linings as well as the joints themselves are liked by the miners.

Fig. 10 (Plate XIV.) is another instance of local enrichment, determined in this case by a single cross-joint, and occurring 1,635 feet above the river. The vein carries good ore at A, and in the bottom of the face at B the ore is seen to pinch out to a few inches in width.

Fig. 11 (Plate XIV.) is a rough sketch of a local bunch of ore near the same spot, the axis of which is horizontal. It is connected at one end with a flat joint filled with clay.

The normal structure of the vein is a roughly banded one, but the bands are unsymmetrical, and would appear to have been produced by the partial or complete alteration or substitution of the country-rock. Here and there, indeed, the filling is unaltered and consists of parallel layers of felsite showing flow-structure, but far more frequently there are evidences of considerable alteration having taken place.

Sometimes, the alteration is in the direction of silification.* Fig. 12 (Plate XV.) is a sketch of an open-working on the lode about 1,760 feet above the river. The best ore is 6 feet thick on what was believed to be the hanging-wall side of the vein. However, above this are several layers of highly quartzose country (quartzite†), probably of very low-grade value, while the foot-wall is conglomeratic or brecciated in structure, consisting of white fragments of felsite and quartz spotted with ore (low-grade).

In Fig. 13 (Plate XV.) sketched in a working 1,635 feet above the river, the best ore, 2 feet wide, is on the foot-wall side, and con-

* "In rocks rich in silica, such as rhyolite or quartzite, the tendency to silicification (probably by reason of mass-action) is greater than in more basic rocks in the same district," Prof. Waldemar Lindgren, "Metasomatic Processes in Fissure-veins," *Transactions of the American Institute of Mining Engineers*, 1900, vol. xxx., page 601.

† The term "quartz-rock" would be more appropriate.

sists of two bands of ore, several inches thick, separated by about 1 foot of mineralized quartzose country-rock. On the hanging-wall side is a streak of high-grade shipping ore, varying from ½ to 3 or 4 inches in width.

Near the same spot, the section shown in Fig. 14 (Plate XV.) was exposed. The local strike is north 67½ degrees west, and the dip northward 53 degrees. The centre of the vein consists of clay with lenticular wedges of quartzose country-rock; the best ore is on the hanging-wall and consists of a pay-streak or *hilo* from 4 to 6 inches thick. Here kaolinization,* as well as silicification, has occurred, and the vein would appear to have been formed by replacement or substitution.

The lenticular masses of rock afford no evidence of having fallen from one of the walls into an open space, as there are no signs of "crustification" (Posepny); they are evidently altered portions of the country-rock *in situ*.

The brecciated structure of Figs. 12 and 18 (Plate XV.) may possibly have been formed by gradual substitution, portions of the country-rock having survived, as it were, the metasomatic processes;† but more probably there was considerable local movement along one wall of the vein, resulting in crushing and the production of a friction-breccia.

In Fig. 15 (Plate XV.) sketched from the same working, the centre of the vein is occupied by a lenticular mass of altered felsite, the axis of which would appear to correspond with a shear-plane. The best ore occurs here on the foot-wall side.

In Fig. 16 (Plate XV.) from the same workings, the vein is seen to be curved in cross-section, and is formed of altered country and ore mixed, while a wedge-like mass of rock is seen in the lower

* "Long ago . . . Forchammer (1835) and Bischoff (1855), followed by many more recent authorities, ascribe kaolinization to the attack of water carrying carbonic acid, and this must be the correct view for the following reasons:—(1) Kaolinization is in many cases a surface-process, effected by the weak carbonic-acid solutions of surface-water; (2) at somewhat greater depths the felspars of the rocks are often converted by similarly weak carbonic-acid waters into kaolin, sericite, etc., as well as calcite," Prof. J. H. L. Vogt, "Problems in the Geology of Ore-deposits," *Transactions of the American Institute of Mining Engineers*, 1901, vol. xxxi., page .

† About 20 years ago, the writer observed what appeared to be brecciated structure in one of the lead and zinc-bearing veins of Cardiganshire, South Wales; on breaking specimens, however, he was surprised to find that it was in reality a pseudo-breccia, the country (metamorphosed clay-slate of Silurian age) was not in separate fragments cemented by ore and veinstone, but the pieces were more or less connected cross-wise as well as longitudinally, so that the mineral solutions would appear to have first honeycombed the rocks, as it were, and afterwards to have filled the interstitial spaces with minerals.

portion of the section. There is no evidence, however, that this mass has fallen from the hanging-wall, it is country-rock, which has been altered *in situ*.

Fig. 17 (Plate XV.) sketched from a rise in a working about 1,650 feet above the river, shows considerable kaolinization, a portion of the filling consisting of bands and bunches of red clay,* divided by greatly altered country-rock. The ore is composed of cavernous quartz, with red oxide of iron in white and black clay. A lenticular mass of altered felsite is traceable in the vein, wedging out below. The abrupt bending of the layers on the foot-wall side is remarkable, and is probably the result of local crushing. Slickensides were observed on the foot-wall dipping 10 degrees in a southerly direction. The felsite is grey when hard, and blue or white when kaolinized, and in places it is converted into pure kaolin.

Where the lode consists of highly silicified country (quartz-rock) it is almost invariably of very low-grade value, but where, on the contrary, there is moderate kaolinization as well, the values in silver and gold are much higher.

The occurrence of *caracol* ore has already been mentioned. This ore is generally of low-grade value and may be in streaks 2 or 3 inches wide on either side of a vein of quartz. The layers may appear in cross-section as straight lines, or wavy, or of circular form, or they may be contorted and quite irregular. Examined through a microscope the ore is seen to be composed of a number of thin siliceous bands. When the black layers are thick the ore is of better grade—the black colour no doubt indicates the presence of argentite. The ore has frequently a great resemblance to the fluidal structure† of the felsite-country even to the very colour, and the writer regards it as strong evidence of replacement of country-rock by quartz and argentite. It is merely another form of silicification, perhaps of more recent date than that of the rest of the filling. Fig. 18 (Plate XV.) is one example of its occurrence in the vein.

Fig. 19 (Plate XV.) shows another occurrence of *caracol* ore, and its relation to the felsite country-rock showing flow-structure.

* In this district, the miners term china-clay (kaolin) *tofo* or *chile*, reserving the term *caliche* or *cantara* for ordinary white decomposed clay.

† Prof. Grenville A. J. Cole, writing of the banded and fluidal structure of rocks, says :- "Like surfaces of foliation, both the bands and lines of flow show frequent involutions and contortions."

The shoots of ore in this mine are either vertical, or have a tendency to pitch north-westward at a high angle, following the dip of the main joints.

A little lower down the river, there is an interesting old Spanish working. A double-compartment shaft, 10 feet by 6 feet, inside measurement, the collar of which, built of solid masonry, is 16 feet high, has been sunk on one side of the bed of the river (Figs. 20 and 21, Plate XV.), which is covered only at flood-times. A masonry wing-dam confines the water to one side of the shaft. A vein, 6 feet wide, coursing north 15 degrees west and dipping eastward 67 degrees crops out along the right bank of the river. The country-rock consists of grey and purple andesitic breccia, and the ore contains much blende and iron-pyrites. A branch-vein or feeder, near the shaft, runs about due east-and-west and dips eastward 70 degrees.

Rich specimens of silver-ore can still be picked out of the dump, and as the ruins of a town exist here, with a church and streets well laid out, in which a number of *arrastres* were found, it is reasonable to conjecture that at the point where the two veins meet a rich shoot of ore was found. Mr. H. G. Ward* says "the lode was extremely rich in native silver, and in the principal mine solid masses of this metal had been actually taken out when the progress of the works was stopped by water." Locally nothing is known of the mine, or of the inhabitants of the deserted town. A tradition, indeed, exists that the latter were massacred by Indians early in the nineteenth century, and as the town is built in a narrow valley, from which escape would have been very difficult if the valley were attacked simultaneously from both ends, the above tradition may have had its origin in fact.

The Candelaria mine, near San Dimas, has been in bonanza for some years. The main vein courses north 55 degrees east, dips north-westward 50 degrees, and is from 6 to 8 feet wide. The country-rock is described as calcareous diorite, but a sample taken by the writer proved, on examination with a microscope, to be a brecciated felsite. A dyke of basalt, probably of more recent age than the vein-filling, has been met in the mines. The ore consists of argentite, native silver, iron-pyrites, and a little

* *Mexico in* 1830, 2 volumes.

galena and gold, forming ribbons and lumps in a hard compact quartz mixed with calcite.

According to Mr. H. G. Ward,* in the old Candelaria mine the ore was found in vertical shoots (*clavos à pique*) separated by country-rock. In a horizontal length of 1,375 feet four of these shoots were found.

The same author states that the mine of Araña (? in the same district) contained between two small strips of rich ore a cavity filled (like the *bovedas*† of the mine of Zavalo at Catorce) with a rich metallic dust, composed almost entirely of gold and silver, also very rich shoots of small extent horizontally but constant vertically.

Besides the ore and veinstones already mentioned, the following minerals have been found in the Candelaria mine:—Argentiferous tetrahedrite (grey copper-ore or fahlerz), cuprite (red copper-ore), carbonate of copper (malachite), hydrous silicate of copper (chrysocolla), cerussite (lead carbonate), smithsonite (zinc carbonate), and oxides of iron and manganese. In this mine, *metal caracol*, with a conchoidal texture, occurs in calcite.

The mine, which has already been worked to a depth of nearly 1,000 feet, can be opened up by tunnels to a total depth of 3,500 feet.

The composition of the rich ore is as follows, I. being a partial, and II. a complete analysis:—

| | I. Per Cent. | II. Per Cent. |
|---|---|---|
| Gold ... ... ... ... ... | 0·41 ... ... | 0·55 |
| Silver ... ... ... ... ... | 2·37 ... ... | |
| Copper ... ... ... ... | 3·41 ... ... | 0·24 |
| Lead ... ... ... ... ... | 6·75 ... ... | 0·34 |
| Zinc ... ... ... ... ... | 2·46 ... ... | 0·92 |
| Antimony ... ... ... ... | trace ... ... | — |
| Iron ... ... ... ... ... | 5·68 ... ... | 1·32 |
| Manganese ... ... ... ... | ... ... | trace |
| Silica ... ... ... ... ... | 74·08 ... ... | 83·00 |
| Lime ... ... ... ... ... | — ... ... | 6·27 |
| Alumina ... ... ... ... | — .. ... | 0·86 |
| Carbonic acid .. ... ... ... | — ... | 3·01 |
| Sulphur ... ... ... ... | — .. ... | 0·41 |
| Water .. ... ... ... ... | ... ... | 0 81 |
| Oxygen and loss ... .. ... | — ... ... | 2·26 |
| | 95·16 | 99·99 |

* *Mexico in* 1830. 2 volumes.

† A chamber-deposit (*camara aboredada*) in which the ore is of a loose texture (Spanish, a vault or arch), and *boredal* is a variation of the same word.

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TION.

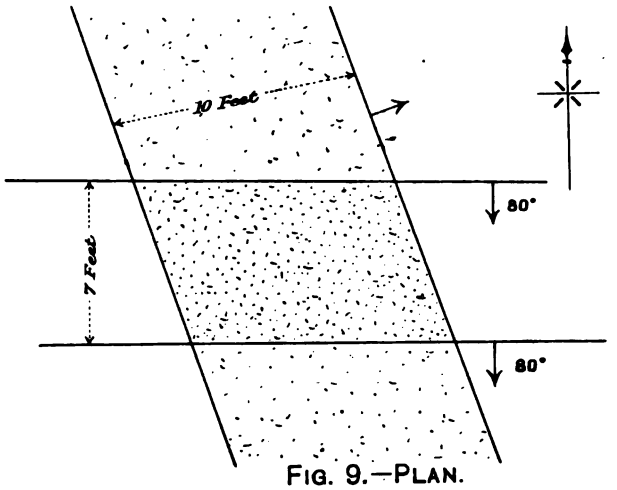


FIG. 9.—PLAN.

*Scale, 8 Feet to 1 inch.*

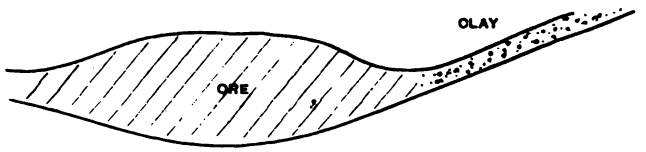


FIG. 11.—LONGITUDINAL-SECTION.

*Scale, 2 Feet to 1 Inch.*

ONE

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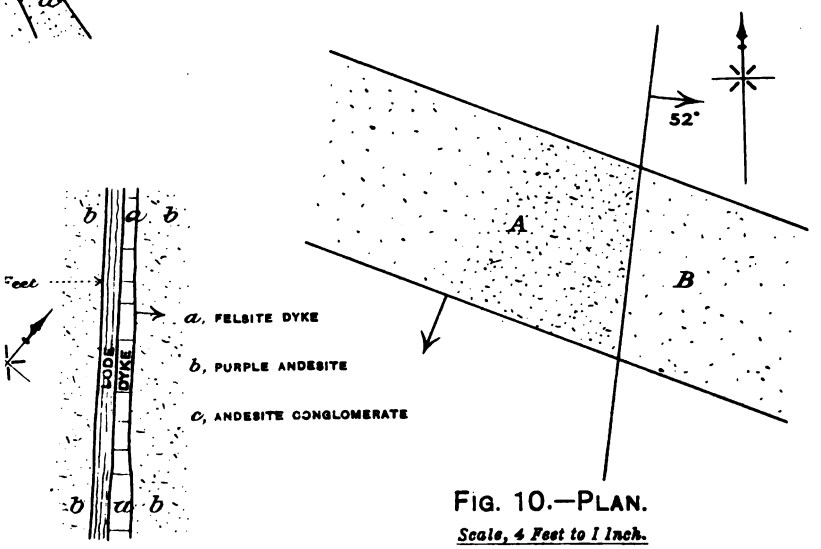


FIG. 10.—PLAN.

*Scale, 4 Feet to 1 Inch.*

Inch.

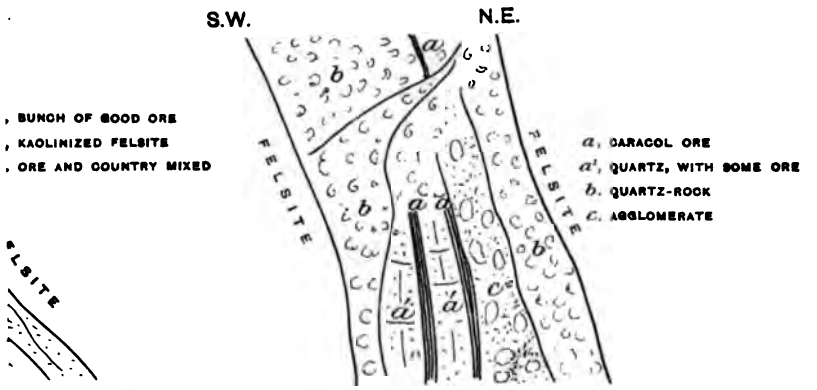


FIG. 18.—CROSS-SECTION.

*Scale, 4 Feet to 1 Inch.*

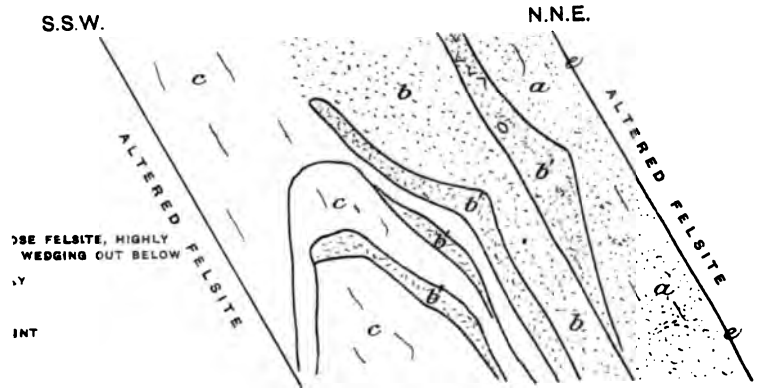


FIG. 17.—CROSS-SECTION.

*Scale, 4 Feet to 1 Inch.*

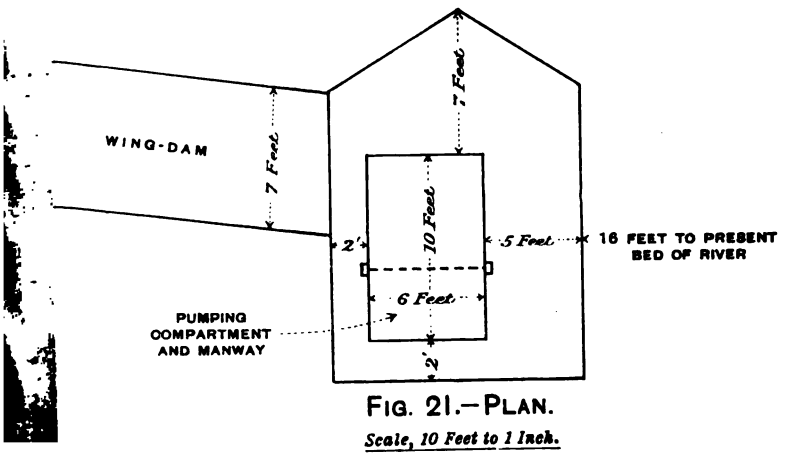


FIG. 21.—PLAN.

*Scale, 10 Feet to 1 Inch.*

An average assay-value of 111 samples gave 55·86 dollars (gold) per ton. The ore contains no chloride of silver, and is free-milling. It is said that from 85 to 88 per cent. of its assay-value can be extracted.* The comparatively high percentages of copper and lime in these analyses is notable. The samples were evidently of oxidized ore from above water-level.

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The PRESIDENT (Mr. J. S. Weeks) moved a vote of thanks to Mr. Halse for his valuable notes.

Mr. WILLIAM LOGAN seconded the motion, which was very cordially approved.

* The above facts with regard to the San Dimas mine (which the writer had not time to examine), have been gleaned mainly from a report published several years ago by the American company working the mine.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

## EXCURSION MEETING,

HELD AT WASHINGTON COLLIERY, MAY 13TH, 1902

## WASHINGTON COLLIERY.

Two shafts, situated about ½ mile from Washington station, on the North-eastern railway, are being sunk on the dip side, and about 1 mile from Washington colliery. A preliminary bore-hole was made to the stone-head, and proved the following strata:—

| No | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface Ft. | In. |
|---|---|---|---|---|---|
| 1 | Soil ... ... ... ... ... ... | 1 | 3 | 1 | 3 |
| 2 | Yellow sand ... ... ... ... ... | 34 | 6 | 35 | 9 |
| 3 | Grey sand, full of water ... .. ... | 41 | 3 | 77 | 0 |
| 4 | Blue clay ... ... ... .. ... | 0 | 1 | 77 | 1 |
| 5 | Grey sand, full of water ... ... ... | 2 | 4 | 79 | 5 |
| 6 | Clay, with boulders ... .. ... | 12 | 11 | 92 | 4 |
| 7 | Loamy clay ... ... ... .. .. | 5 | 2 | 97 | 6 |
| 8 | Very hard clay, with large boulders . | 9 | 7 | 107 | 1 |

Owing to the occurrence of water-bearing sands to a depth of 79 feet 5 inches, a modification of the Poetsch freezing-method of sinking has been adopted. The work is being carried out by Messrs. Gebhardt and Koenig of Nordhausen, Germany, and it is the first attempt ever made to sink shafts by the freezing process in Great Britain.

The No. 1 pit was sunk in the ordinary way, with a diameter of 24 feet, to a depth of 24 feet. At that point, twenty-two bore-holes were bored in a circle 22½ feet in diameter, and temporarily lined with steel tubes, 6 inches in diameter. Afterwards, flush-jointed steel freezing-tubes, 110 feet long, 4 inches in diameter, and closed at the lower ends, were inserted in each bore-hole, and the temporary casing was removed. Smaller and central copper tubes, 1 inch in diameter, for conveying the brine,

and perforated at the lower ends, were placed inside the freezing-tubes. The tops of the small tubes are connected to an annular pipe, placed near the top of the shaft, and to the delivery-end of a small steam-driven pump, which forces the cooled brine down and through them. The tops of the large tubes are connected to an annular pipe and to the cisterns in which the brine is cooled, whence it is drawn by the brine-pump.

FIG. 1.—WASHINGTON COLLIERY: GLEBE SHAFTS.

The freezing plant comprizes a horizontal steam-engine, with a cylinder, 18 inches in diameter and 24 inches stroke, driving by belt and shafting two horizontal compressors, which deliver the ammonia at a pressure of 150 pounds per square inch. The ammonia passes, at this pressure, through 1,600 feet of 1 inch tube placed in two water-tanks or condensers, through which 4,000 gallons of cooled water circulate per hour, and is mechanically stirred by rotating paddles, and the ammonia becomes liquid. Immediately after leaving the condensers, the liquid ammonia passes through valves, where the ammonia is evaporated and the pressure is reduced to 14 pounds per square inch, produced by the exhausting action of the compressing-pump. At this reduced pressure, the gaseous ammonia passes along 2,000 feet of 1 inch tubes immersed in three cisterns or refrigerators, and then returns to the compressor. The refrigerators are filled with brine, which is mechanically stirred by rotating paddles, the

solution containing from 21 per cent. in the early stage of the freezing to 26 per cent. of chloride of magnesium at the present time.

About 6 months were spent in erecting the plant and boring and preparing the bore-holes. Freezing commenced on March 23rd, 1902, with one compressor, and on April 1st, the second compressor was started. The temperature of the brine, at the commencement, varied from — 8° to — 11° Cent., on going to the

FIG. 2.—VIEW OF TOPS OF FREEZING-PIPES IN NO. 1 SHAFT.

shaft; and in the return-tubes the temperature varied from — 6½° to — 9° Cent. On April 2nd, the temperature of the brine fell to — 16° Cent., and has gradually fallen, until, at the present time, it is about — 21° Cent. The brine returning from the shaft is generally about 2° Cent. warmer than when entering.

The strata were frozen to a radial distance of about 5 feet, around each pipe; but as the centre of the shaft was not frozen the quicksand was easily removed. The sinking at the No. 1 shaft through the frozen quicksand was commenced on May 5th, and completed on May 19th, and the shaft is being lined with

brickwork set in cement, with an inner diameter of 14 feet. Ten men were employed in the sinking of the shaft through the frozen ground, by picks and wedges, in three shifts of 6 hours each, with 12 hours' rest, and the sinking proceeded continuously. This shaft will be sunk to a depth of about 720 feet by ordinary methods, to the Hutton seam.

At No. 2 shaft, boring operations are now proceeding for the purpose of making the bore-holes for the freezing-pipes.

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Mr. A. L. Steavenson moved a hearty vote of thanks to the owners of Washington colliery for their kindness in allowing the members to see that very interesting freezing system at work. It was fifty years since he had signed his indentures as a mining-engineer, and yet he was still acquiring valuable information.

Mr. R. Donald Bain (H.M. Inspector of Mines) seconded the vote of thanks, which was cordially approved.

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# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 14TH, 1902.

MR. J. G. WEEKS, PRESIDENT, IN THE CHAIR.

## DEATH OF MR. ROBERT ROBINSON.

The PRESIDENT referred in sympathetic terms to the death of Mr. Robert Robinson: one of the oldest members of the Institute, a Vice-President for many years, and one who had unfailingly taken a great interest in the Institute and at all times most helpfully assisted in advancing its welfare. He proposed a vote of condolence and sympathy with Mrs. Robinson and her family, in the irreparable loss that they had sustained.

Prof. HENRY LOUIS seconded the vote, which was carried unanimously.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings on May 10th and 24th and that day.

The SECRETARY read the balloting-list for the election of officers for the year 1902-1903.

The following gentlemen were elected, having been previously nominated:—

HONORARY MEMBERS—

Mr. FREDERICK AUGUSTUS GRAY, H.M. Inspector of Mines, 7, Victoria Square, Penarth, near Cardiff.

Mr. WILLIAM HENRY PICKERING, H.M. Inspector of Mines, Lawn House, Doncaster.

MEMBERS -

Mr. THOMAS BOUSFIELD, Under-manager, Wallsend Colliery, Wallsend, New South Wales.

Mr. WILLIAM BRAIDFORD, Jun., Colliery Manager, South Garesfield Colliery, Lintz Green, R.S.O., County Durham.

Mr. CHRISTOPHER ROBERT CORNING, Mining Engineer, 36, Wall Street, New York. United States of America.

Mr. EMILIANO DE LA CRUZ, Mining Engineer and Prospector, 9, Calle de Malasana, Madrid, Spain.

Mr. FRANCIS IVAN LESLIE DITMAS, Mining Engineer, c/o Colonel F. F. Ditmas, Royal Artillery, Frimley Green, Surrey.

Mr. SOSTHENES DOISE, Civil Engineer, Chaton, Seine et Oise, France.

Mr. FRANCIS THEODORE FREELAND, Mine Manager and Consulting Mining and Mechanical Engineer, P.O. Box 1016, Aspen, Colorado, United States of America.

Mr. ROBERT WILLIAM HEADS, Mechanical Engineer, Greenbushes, Western Australia, Australia.

Mr. ROBERT HUNTER, Assistant Inspector of Mines, Gympie, Queensland, Australia.

Mr. JOHN ELIAS JONES, Consulting Mining Engineer, 1, Holmes and Dun Chambers, Durban, Natal, South Africa.

Mr. TALBOT RICHARD LONSDALE, Overman, Lamesley, Gateshead-upon-Tyne.

Mr. HARRY ARTHUR MUNDLE, Mining Engineer, 22, Hood Street, Morpeth, Northumberland.

Mr. CHARLES H. POWELL, Mechanical Engineer, "Missouri," Lyons Street, Eagle Junction, Prisbane, Queensland, Australia.

Mr. WILLIAM RICHARD RUMBOLD, Mining Engineer, Mill House, Holmwood, Surrey.

Mr. RICHARD SUTCLIFFE, Mining Engineer and Colliery Manager, Horbury, near Wakefield. Yorkshire.

Mr. UMFREVILLE PERCY SWINBURNE, Mining Engineer, Capheaton, Newcastle-upon-Tyne.

Mr. JACKSON SWINDLE, Colliery Manager, Swalwell, R.S.O., County Durham.

Mr. WILLIAM HENRY WALL, Mechanical Engineer and Colliery Manager, 46, Haliburton Street, Nanaimo, British Columbia.

Mr. WALTER HARVEY WEED, Geologist, United States Geological Survey, Washington, D.C., United States of America.

Mr. RICHARD WOOD, Mining Engineer, Barley Brook Foundry, Wigan.

ASSOCIATE MEMBERS—

Mr. HORACE WILLIAM JARVIS, West Dyke, Coatham, Redcar.

Mr. ARTHUR HERBERT SMITH, Broad Street House, London, E.C.

Mr. JAMES VALENTINE, 1, West View, Horwich, Lancashire.

ASSOCIATE—

Mr. THOMAS SMITH, Assistant Under-manager and Surveyor, Netherton Colliery, near Newcastle-upon-Tyne.

STUDENTS—

Mr. JOHN FREDERICK FOGGO, Mining Student, Netherton Colliery, near Newcastle-upon-Tyne.

Mr. FRANCIS GEORGE MAYNARD, Mining Student, 5, New Houses, Philadelphia, Fence Houses, County Durham.

Mr. HARRY PALMER, Mining Student, The Manor House, Medomsley, R.S.O., County Durham.

# THE NORTH OF ENGLAND INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

EXCURSION MEETING,
HELD AT SOUTH DURHAM COLLIERIES, JULY 11TH, 1902.

## SOUTH DURHAM COLLIERIES.

### I.—PUMPING PLANT.

The pumping plant comprizes a compound steam-engine, a continuous-current generator, two electric motors and two high-lift ram-pumps.

(*a*) *Engine.*—The horizontal compound Robey engine has high-pressure and low-pressure cylinders, 18 inches and 30 inches in diameter respectively by 40 inches stroke; and it develops 440 in licated horsepower, at 90 revolutions per minute and a steam-pressure of 100 pounds per square inch. The engine, with automatic trip expansion-gear to both cylinders, is fitted with a flywheel, 16 feet in diameter, grooved for 14 driving-ropes, each 1½ inches in diameter.

(*b*) *Dynamo.*—The Scott-and-Mountain six-pole generator is constructed for an output of 220,000 watts, or 400 ampères by 550 volts at the terminals, at an approximate speed of 400 revolutions per minute. The generator is fitted with a pulley, grooved for 14 driving-ropes, each 1½ inches in diameter.

(*c*) *Main Switchboard.*—The main switchboard consists of a marble panel fitted with the following instruments and switches: —A double-pole quick-break lever-switch for a current of 500 ampères; an automatic overload circuit-breaker suitable for a current of 500 ampères; an ammeter to read to 500 ampères; a volt-meter to read to 600 volts; and a shunt-regulating switch and resistance.

(*d*) *Cables.*—The main cables, for conveying current from the generator-terminals to the main switchboard, and from the main switchboard at the Harry pit to the pump switchboard at the John Henry pit, a distance of 2,550 feet, consist of 4 overhead conductors of bare copper wire, each conductor being composed of 19 wires of No. 11 standard wire-gauge, and supported on poles with cross-arms, and earthenware insulators. Two cables, each 450 feet long, for conveying the current down the shaft to the pumps, are composed of 61 wires of No. 13 standard wire-gauge, having a sectional area of 4 square inches. These cables are insulated with vulcanized bitumen, served with jute and compound, protected by a double armouring of galvanized-steel wires, and finally covered with jute and compound.

(*e*) *Main Pumps.*—There are two main shaft-pumps, with rams 11 inches in diameter by 18 inches stroke, each capable of delivering 500 gallons per minute to a height of 400 feet, at an approximate speed of 28 revolutions per minute. The pumps are rope-driven by the motors.

(*f*) *Electric Motors.*—The Scott-and-Mountain multipolar motors for driving the pumps are each constructed for an output of 120 effective horsepower, at 450 revolutions per minute by a current of 450 volts at the terminals. Each motor is fitted with 10 cotton driving-ropes, for transmitting the power to the pumps.

(*g*) *Motor-room Switchboards.*—Two switchboards are provided, one for each pump, each board consisting of a marble panel carrying the following instruments and switches:—A double-pole main switch for a current of 200 ampères; an automatic overload and no voltage circuit-breaker; an ampère-meter to read to 200 ampères; a volt-meter to read to 600 volts; and a shunt-regulating switch and resistance, for varying the speed of the motors.

Two Scott-and-Mountain single-pole liquid-starting switches are provided for starting and stopping the electric motors.

## II.—Coal-cutting Plant.

The coal-cutting plant consists of 3 Goolden dynamos with an output of 36,000 watts each at 350 volts. These are driven by the Robey compound engine recently erected for driving the electric pumping plant.

At present, 5 coal-cutting machines of the Goolden bar-type are at work—3 in the Harvey and 2 in the Hutton seam. One machine in each seam is driven by a 25 horsepower four-pole enclosed motor, and the others by 18 horsepower two-pole enclosed motors.

This plant was erected by the Electrical Coal-cutting Contract Corporation, and the cutting was done by that company at a fixed price per ton, but the plant was afterwards bought by the South Durham Coal Company.

In addition to the coal-cutting plant, the generating plant is also driving a three-throw pump, with 6 inches rams, pumping about 100 gallons per minute from dip-workings against a head of 120 feet; and a 4 inches Gwynne centrifugal pump is delivering about 130 gallons per minute against a head of 60 feet.

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Mr. Fenwick Darling read the following paper on the "Electric Pumping-plant at the South Durham Collieries":—

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# ELECTRIC PUMPING-PLANT AT SOUTH DURHAM COLLIERIES.

By FENWICK DARLING.

The John-Henry pit was sunk to the Main coal-seam, 312 feet deep, about 62 years ago.

The Main and Five-quarter coal-seams were worked from this shaft until 1877, when they were abandoned, the seams being nearly exhausted. Since that time, the shaft has only been used as a pumping-station for the purpose of draining these seams: this being effected by means of a Cornish pumping-engine, with a cylinder, 72 inches in diameter and 8 feet stroke, working a bucket-lift, 21 inches in diameter.

In course of working eastward in the Brockwell seam, from the Harry pit, a fault was encountered, throwing the seams down to the east, from 270 to 300 feet. A considerable distance was driven beyond this fault in the Harvey seam, which was found on nearly the same level as the Brockwell seam.

About 3 years ago, it was decided to sink the John-Henry shaft down to the Hutton seam, by means of which the Hutton and Low Main seams would be won, and could be worked, on the west or rise side of the fault, and the Main and Five-quarter coal-seams on the downthrow side.

The shaft being only 12 feet in diameter, there was not room to put in cages sufficiently large to admit of 2 tubs being drawn on one deck and still to retain the old pumping arrangement; and it was necessary that some other system of pumping should be adopted, in order that the shaft should be left clear for coal-drawing.

There were three methods by which this could have been done:—(1) A direct-acting steam-pump could have been placed in the Main coal-seam: (2) a large air-compressing plant could have been placed on the surface at the John-Henry pit, with pumps, worked by compressed air, in the Main coal-seam: or (3)

an electric generating-plant could be placed at the Harry pit about ½ mile distant, and the current carried by cables to pumps placed in the Main coal-seam.

The first scheme was objectionable for several reasons:—The chief being the necessity for erecting boilers of high pressure at the John-Henry pit, and owing to the upcast shaft being ½ mile distant, there would of necessity be great difficulty in dealing with the steam in seams with blue-metal roofs. The second scheme would also have involved a large outlay in air-compressing and boiler-plant at the John-Henry pit, and probably it would be less efficient in working than an electrically-driven plant.

The third scheme was adopted, and the following are the principal reasons which led to that decision:—(1) The necessity of increasing the plant on the surface at the John-Henry pit was entirely avoided; (2) by keeping the generating-plant at the Harry pit, where a large boiler-plant is already in existence, a great saving in coal is effected; and at nights and week-ends, when coal-drawing is not in operation, there is sufficient steam generated by the waste heat from the coke-ovens to drive the electric plant; and (3) the concentration of the plant would allow of better and more efficient supervision, and reduction of wear-and-tear, by having all the electric plant driven by one thoroughly efficient and reliable engine.

The generating-plant and pumps are capable of pumping the whole of the water, at present met with in the seams, at nights; and, so long as this is the case, very little steam beyond that produced by the coke-oven gases will be required. It is possible that a considerable increase of water may be encountered at the large fault, when it is reached in these seams; and in that case it will only be necessary to erect an additional boiler. By driving the pumps night-and-day there will be no difficulty in dealing with 1,000 gallons of water per minute during the 24 hours, as well as running the coal-cutting machines, and the hauling in the Hutton seam, which will be driven by this plant.

The steam-engine, as well as the whole of the plant, is of strong and substantial make, and affords an ample margin of power. It has been working since January of this year, and has not, as yet, given the slightest trouble.

The PRESIDENT (Mr. J. G. Weeks), in moving a vote of thanks to the owners for their kindness in allowing the members to visit the South Durham collieries, and to Mr. Fenwick Darling for his interesting paper, said that the erection of the new plant had been efficiently and economically carried out, and afforded an excellent example of the work of a skilful engineer.

Mr. HENRY LAWRENCE seconded the resolution, which was cordially approved.

# THE SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE INSTITUTE OF MINING ENGINEERS.

## GENERAL MEETING,

HELD AT THE UNIVERSITY, BIRMINGHAM, JUNE 2ND, 1902.

PROF. CHARLES LAPWORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting and of Council Meetings were read and confirmed.

The following gentleman was elected:—

MEMBER

Prof. R. A. S. REDMAYNE, The University, Birmingham.

## MINING COURSE.

Prof. LAPWORTH said that the following provisional curriculum of the mining course to be followed in the Birmingham University had that afternoon been approved by the joint advisory committee of representatives of this Institute and of the North Staffordshire Institute of Mining and Mechanical Engineers:—

The Mining Department of the Birmingham University has been founded by the University authorities in order to meet the requirements of the large mining community of the Midlands, and at the same time to afford mining men from other parts of Great Britain and elsewhere theoretical and practical instruction in the various branches of mining generally. As Birmingham is situated in the centre of England and Wales, with coal-fields either in its neighbourhood or within a short distance by rail, the University Mining Department might soon form the natural centre for all those interested in mining matters in the English Midlands. Especially would this be the case as regards coal-mining, for the student in this branch would have an almost unrivalled opportunity for inspection and practical illustration among the many and varied coal-fields of the Midlands.

Further, as the Mining Department of the University would be well furnished with the materials and apparatus for the teaching of metalliferous-mining, this would also form a natural and important part of the mining curriculum. Here, again, the central position of Birmingham was most advantageous. The student would be able, during special weeks in the year, to visit at no great cost the metalliferous-mining districts of Cornwall and Wales, and study the practice of metalliferous-mining on the spot.

As the British mining law stands at present with respect to coal-mines, a mine-apprentice is obliged to have had 5 years' actual underground experi-

ence before he can enter for the examination for the certificate of competency to manage a coal-mine. Consequently, few young men after leaving school can afford the additional time (say 3 years) requisite to take a mining degree —namely, 8 years in all. The result is that we, in Britain, are not turning out mining-engineers who are in a position to compete with those of Germany and, more especially, with those of America, in point of knowledge as well as in experience: namely, men who bring a trained mind to bear upon their work.

If the degree of mining-engineer acquired after, say a 3 years' course of training at the University, were allowed by the Government to count for 2 out of the 5 years' necessary apprenticeship, it would greatly conduce to the success of Birmingham and other Universities where a mining-school is in operation, and be the means of turning out a class of mining-engineers far better equipped mentally for their duties than are those of the present day. Under such a plan, a mining candidate would still be able to enter for examination, under the 5 years' practical-experience clause, for a colliery-manager's certificate.

Since the passing of the Coal-mines Regulation Act, 1887, which contains the clause requiring 5 years' practical underground experience, County Councils have come into existence and have in most mining localities established mining lectureships and classes. Such mining classes offer means of educating the mining candidates in a certain amount of scientific mining. If the County Councils would further extend their sphere of usefulness by establishing scholarships to be competed for by the students attending such classes, these scholarships would enable such students subsequently to attend the University course for a degree in mining. This would not only be a means of sending to the University a very desirable class of students, but the chance thus afforded to mining men of passing through the local mining classes onward to those of the University, would, almost certainly, attract a larger number of students to the mining classes themselves.

It is not proposed that the time of mining students at the University should be devoted specially to theoretical work; much of it would be of an intensely practical character. There will be weekly visits to the mines of the neighbourhood, and 4 or 5 weeks will be devoted by the students each year, in company with the professor, to the inspection and study of some group of metalliferous mines in Britain or abroad (summer mining-school).

Before entering upon the study of any of the mining courses, projected in the syllabus, intending mining students should, if possible, devote one year of their mining apprenticeship to practical work at the mine, as it had been shown by repeated examples that young men who have had some practical experience of the mining profession before entering upon what may be called the scholastic part of their professional training, more clearly perceive the necessity and value of scientific training, and, therefore, pursue their studies with greater zest and more satisfactory results.

The courses have been so arranged as to meet the requirements of:—(1) Those who intend becoming practising and consultative mining-engineers, where a thorough knowledge of mining in all its branches is necessary, (2) intending colliery-managers, (3) metalliferous mining-engineers, (4) teachers of mining, (5) mining-surveyors, and (6) land-and-estate agents, land-owners, owners of collieries, and those interested in mines and quarries generally.

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Mr. DANIEL JONES' paper on "Legislation and the Ownership of Properties containing Coal" was read as follows:—

# LEGISLATION AND THE OWNERSHIP OF PROPERTIES CONTAINING COAL.

By DANIEL JONES.

The appointment of a Royal Commission on Coal-supplies seems to afford an opportunity of ventilating a subject of much importance from a national point of view, namely, What legislative action is needed to enable the nation to avail itself of the coal-supplies that exist beneath numberless small properties, which are not necessarily available for mining purposes, by reason of the control being in the hands of individuals who for a variety of reasons, may be unwilling that they should be worked, or are unwilling to grant fair and reasonable terms for working them.

Whether the scope of the enquiry entrusted to the Royal Commission on Coal-supplies may be expanded under the terms expressed in the Royal warrant so as to include such an enquiry, is doubtful, but the following words might possibly include it: "or through a change in the customary term and provisions of mineral leases, and whether the mining industry of this country under existing conditions is maintaining its competitive power with the coal-fields of other countries."

It is of little use to measure up and declare the number of tons of unworked coal lying in the ground unless such reasonable conditions can be offered by the owners, as to induce capitalists to embark in the adventure of mining them. We have to look forward to a condition of things such as we have not before experienced. It is now 36 years since the Royal Coal Commission of 1866 was appointed. We are already face to face with the necessity of deep mining for our coal-supplies, and before another 36 years have passed the need for deep mining will have become general. Depths of 1,500, 2,000 and 2,500 feet are now being attained, and in one case workings are carried on at a depth of 3,600 feet below the surface.

We know that deep sinkings entail large outlays of money and consequently large areas must be secured before any attempt at sinking is made. In the case of large estates under one ownership, terms may be made in the interests of both landlord and lessee, but when a number of small estates have to be aggregated together to form a mining area, the difficulties, under the existing ownership of mines and minerals, become almost insuperable.

Around the margins of known coal-fields where a considerable population is grouped and where wealth is accumulated from the working of the coal-fields and the attendant industries, the tendency is for properties to be numerous and comparatively small, while further away from the coal-areas they are larger. But it is in the vicinity of these small properties that one may expect the first sinkings to be chosen, because they are near to boundary-faults, and prudent miners will naturally select sites contiguous to the already proved and worked coal-field rather than plunge into the unknown regions of the unproved coal-field.

For an example of such small properties we may look along the western boundary-fault of the South Staffordshire coal-field; and when the writer speaks of small properties he means from 50 to 100 acres, which are small when compared with 3,000 or 4,000 acres, which would be required to justify deep sinkings.

As the law stands to-day, we are in this position: A number of small properties are known to contain coal, and they are held by the owners under varying conditions; one is a freeholder and has power of sale or leasing; another is a tenant for life; another is a leaseholder for a long time of the surface, and has control of it; another is a copyholder, and not entitled to work the minerals, and the lord of the manor, who is entitled to the minerals, can only reach them by sinking on a piece of freehold which he acquires for the purpose of sinking, but it is not suitably situated for a shaft to win the rest of the mines; and other properties are held jointly by several interested persons.

Then arise new difficulties: We will suppose that conditions are secured for the lease of a property of some 800 acres, not lying within a ring-fence, but somewhat scattered. The terms are reasonable, having regard to the proofs which have to be made and the uncertainty of the venture and the large working cost and heavy outlay attendant on mining at great depths. The

800 acres are more or less intermingled with lands of smaller proprietors, whose properties are essential to the completion of the scheme. What happens? They know that a proof is to be made by boring in the adjoining estate, and they prefer to wait until it has been made so that they may, if it is successful, demand the full royalty usually asked for an ascertained coal-seam. They will require the full benefit of wayleaves, both aboveground and belowground. But it would be obviously unfair to the grantor of the mines in the 800 acres at reduced royalties and wayleaves, that lessors of adjoining properties should be offered better terms than he has secured, and if he is prudent he will make it a condition that better terms should not be given to his neighbours, or if they were, that he should have his modified in accordance therewith.

Some of the smaller properties may be residential, and the fear of unsightly mining operations may be urged as a reason for not granting a mining lease, especially in the cases where there is only a life-interest, and no issue.

The knowledge that sinking and development may take 5 or 6 years to accomplish, during which time no advantage would accrue to the owner, but considerable annoyance may be experienced from the traffic of workmen and hauling of materials, might deter a limited owner from entertaining the idea of a grant, especially if he were advanced in years. Every owner wants the shaft sunk on his property, and that his mines should be worked first, though it is obvious that the more distant areas from the shaft should be the first to be worked.

The question of wayleaves, aboveground and belowground, make it almost impossible to aggregate such small properties for mining purposes.

The question is whether the time has not come now, or in the near future, when there must be some legislative action of a fair and broad scope to enable the nation to avail itself of the coal-supplies, which are admitted to be essential to its existence as a manufacturing community: and whether the Royal Commission on Coal-supplies should not reopen the subject, which was partly discussed by the Royal Commission on Mining Royalties appointed in 1889. That Commission obtained evidence as to the laws affecting mining in other countries, from which it will be seen that in no other country except the United States are the laws affecting mines similar to ours.

The mining laws of European nations are more or less founded upon the French law of April 21st, 1810, by which the principle was adopted that "mines and open workings, metalliferous or non-metalliferous, as well as bituminous and other coals, and pyrites, are at the disposal of the nation to this extent only, that these substances cannot be worked unless by the consent and under the superintendence of the nation." The law reserved no royalty to the State. The rights of the State were recognized in the necessity for a concession, and in the duty of the concessionaire to work his minerals under State supervision. As regards the concession, the owner of the surface had a preferential claim, which he could transfer to a third party. But the surface-owner had no claim to any royalty; he could only claim compensation for injury to the surface. The law of 1810 has been modified by the laws of April 27th, 1838; June 17th, 1840; May 9th, 1866; and July 27th, 1880. So that in France the rights of mining concessionaires and owners of land were not held so sacred as they are in this country, but were frequently varied.

The position now in France is that the State is not the owner of the minerals. All that it can do is to give permission to a concessionaire to work minerals that are proved to exist. The owner of the surface has no legal title to the minerals underneath. Minerals belong to no one, until the State confers ownership by granting a concession. Where a concession is forfeited and put up to sale, and no bid is made, it goes to the State. When the State once grants a concession, the concessionaire acquires a right partaking of the nature of real property.

In applying for a right of search under authority of the State three conditions are laid down:—(1) The Mining Department must be consulted; (2) compensation must be paid beforehand to the surface-owner for any land occupied by the searchers; and (3) the surface-owners must be heard before the right of search is granted.

Thus there are two operations, the "right to search" and the "concession to work." The latter confers a right of property in the minerals; the concessionaire can during his life-time work, sell or lease his mineral property; and at his death the concession descends like other real estate to the heirs, but they cannot divide it, and if they do not agree to keep it they must sell or let it.

In France, there is a royalty payable to the surface-owner, the

amount of which is fixed by the State. It may be payable in one of three ways:—(1) In proportion to the minerals extracted; (2) a fixed sum payable in money; or (3) a proportional amount in addition to a fixed sum. The amount varies in different coal-fields. In the basin of the Loire, it amounts to as much as 6d. per ton, but a more usual form of payment is the fixed royalty, which is payable to the surface-owner whether the coal is worked or not, and is quite apart from the payment for surface-damage and varies from ½d. to 1d. per hectare (2½ acres).

The dues payable to the State include:—(1) A fixed, and (2) a proportionate royalty. The former amounts to ½d. per acre, and is payable as long as the concession lasts. The proportional royalty is 5 per cent. of the net product, that is, taking off the value at the pit's mouth, wages, expense of buying and keeping horses in the workings, maintenance of underground workings, expenses of starting and keeping in order all necessary machinery, including all coal consumed by engines, and stores, and a great variety of other expenses, which it is needless here to mention.

There is little doubt that the poor coal-fields on the Continent made it necessary for the public good that there should be some State control. In this country and the United States, so great an abundance of coal has prevailed that lessors and lessees have been able by mutual and reasonable arrangements to produce what is needed at a moderate cost. But the conditions of mining are rapidly altering; we cannot gauge the future by the past; and private rights must be subjected to national needs—a principle pervading our legislation that requires no repetition.

The writer does not propose that we should follow the Continental model or do any injustice to the owner of the minerals, but on the other hand the lessor is not justified in playing "the dog-in-the-manger;" and it seems to him, inevitable in the long run, when such owners cannot be induced to make reasonable terms, that the circumstances should be laid before a State authority comprizing a selection of land-owners, mining-engineers and legal experts, who should have power to fix terms and conditions for leases, after hearing evidence, taking care that proper compensation, security and guarantees are forthcoming for the protection of the grantors.

We have so many cases of awards by juries in cases of compulsory purchase enforced by the provisions of Acts of Parliament

for the public good, that the writer need not advance precedents for what he is proposing. The State mining authority would be a standing body paid for their services, who would give proper time and consideration to their cases, say, such a body as the "Railway Commissioners," and if desirable it should be a department of the Board of Trade. If such a tribunal existed, it would ensure that all available and commercially profitable coal in the kingdom would sooner or later be worked.

In Ireland, we have a very marked illustration of the position presented to the members. Under the Land Purchase Acts, such a subdivision of property and vesting of royalties in small proprietors "would effectually stop or certainly impede any development of the mineral resources of the country." While the principal proprietors of the land place no difficulties in the way of leasing, the small proprietors are very difficult to deal with, and an illustration is given of the purchase of a small piece of unenclosed land (let at 10s. to 20s. per acre) to secure a wayleave, at the rate of £1,000 an acre.

In illustration of his views, the writer might refer to an experience in a recently attempted development of mines adjoining the South Staffordshire coal-field. The scheme contemplated the acquisition of about 4,000 acres of property, lying on the deep side of the boundary-fault of that coal-field. We secured terms for a lease of about 800 acres centrally situated. The projected area contained estates belonging to several owners, and one estate extended to about 2,000 acres. Negotiations were opened with these proprietors, but in no single case did we find a disposition to entertain the idea of using their properties for mining purposes. Since we discontinued negotiations the estate of about 2,000 acres has been broken into hundreds of separate lots, and disposed of by auction. This subdivision renders it now impossible for that area to be taken for mining operations, which must necessarily be conducted at a great depth, although the area contains the rich and productive coal-seams of the South Staffordshire coal-field.

The writer does not suggest that there should be nationalisation of the coal-mines, but that there should be such State control as to enable the mines to be worked on reasonable and proper terms. He is quite aware that even this proposal will take owners of property containing coal by surprise; but the need for the

enquiry has only arisen within the last few years, and it was not seriously dealt with by the Commission on Mining Royalties. It might yet lie dormant for a time, but the existence of a Commission on Coal-supplies seems to afford a proper opportunity for an enquiry. In the case quoted by the writer, the quantity of coal locked up for want of the facilities proposed is (at a low estimate) 100,000,000 tons.

The writer's principal object in bringing this subject before the members is, if possible, to secure an investigation by the Royal Commission on Coal-supplies of a subject, which is very pertinent to the enquiry that they are engaged in making as to the duration of our coal-supplies and other matters relating to coal.

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The PRESIDENT (Prof. C. Lapworth) proposed a vote of thanks to Mr. D. Jones for his paper, and the resolution was cordially approved.

Mr. HENRY JOHNSON said that the points mentioned by Mr. Jones undoubtedly called for consideration by the Royal Commission on Coal-supplies, for what could be the use of taking credit for say 1,000,000 tons of coal for future supplies when it was well-known that it could not be worked? The task of arranging working-areas for the prospective deeper mining of the country was, from experience, not an easy or an inexpensive one. If the present complicated nature of ownership could in some way be consolidated, development would be facilitated and the cost of working reduced. The subject was too important to be fully discussed at the present meeting, happening as it did at a glad time of welcome peace and national rejoicing. He proposed that the further discussion be adjourned.

The resolution was agreed to.

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# THE MINING INSTITUTE OF SCOTLAND.

GENERAL MEETING,
HELD IN THE FREEMASONS' HALL, KILMARNOCK, JUNE 14TH, 1902.

MR. HENRY AITKEN, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

Mr. James McPhail was elected a Councillor in the room of Mr. Michael Ross, deceased.

The following gentlemen were elected:—

MEMBERS—

Mr. JAMES ANGUS, Ochiltree House, Ochiltree.
Mr. RICHARD BERRY, Durie Colliery, Leven.
Mr. JAMES BONAR, 121, Main Street, Bishopbriggs.
Mr. WILLIAM CUTHBERTSON, 10, Kay Park Terrace, Kilmarnock.
Mr. JAMES GAVIN, Townhead Colliery, Carfin.
Mr. GEORGE HALDANE, 208, St. Vincent Street, Glasgow.
Mr. JOHN JEFFREY, Woodend Colliery, Armadale.
Mr. DUNCAN LIVINGSTONE, Merryton Colliery, Hamilton.
Mr. JAMES MORTON, 31, Melville Street, Pollokshields, Glasgow.
Mr. ROBERT SIMPSON, 175, Hope Street, Glasgow.

ASSOCIATE MEMBER—

Mr. ANDREW DARLING, Stane House, Shotts.

ASSOCIATES—

Mr. WILLIAM ARMOUR, Doura Colliery, Irvine.
Mr. ROBERT CUNNINGHAM, Drumley, Annbank, Ayr.

STUDENT—

Mr. THEOPHILUS PATON, 208, St. Vincent Street, Glasgow.

Mr. JOHN HOGG's paper on "The Working of Contiguous, or nearly Contiguous, Seams of Coal" was read as follows:—

# THE WORKING OF CONTIGUOUS, OR NEARLY CONTIGUOUS, SEAMS OF COAL.

By JOHN HOGG.

## I.—The Pyotshaw and Main Coal-seams at Auchinraith Colliery, Blantyre.

The Pyotshaw seam is found at a depth of 756 feet, and the Main seam at a depth of 768 feet, below the surface.

The longwall system of working is adopted.

A section of the seams and contiguous strata is as under:—

| | Ft. | In |
|---|---|---|
| Dark fakey blaes, with sandstone ribs ... ... | 4 | 0 |
| Pyotshaw Coal-seam: **COAL** ... ... ... | 4 | 0 |
| Dark fakey blaes, with sandstone ribs ... ... | 12 | 0 |
| Main Coal-seam: **COAL** ... ... .. ... | 4 | 0 |
| Sandy fire-clay ... ... ... ... ... | — | |

A considerable area of the Pyotshaw seam was exhausted before the Main seam was opened, and it was, therefore, got under the most favourable conditions in regard to the working of the coal and the making and upkeep of roads.

When the Main seam came to be worked under the waste of the Pyotshaw seam it was not found to be affected, nor was the roof in the faces broken in any way; but where the strata between the seams thinned down to 6 or 7 feet in thickness, the roof in the roadways eventually broke through in places to the waste of the Pyotshaw seam, causing extra trouble and expense. The additional expense for repairing roads did not exceed 1d. per ton.

An area of the Main seam was then worked under the Pyotshaw seam, and in its turn was got under the most favourable conditions.

The cost of working the Pyotshaw seam over the waste of the Main seam is likely to be higher than that of the section which was worked over the solid Main seam. The rates paid for getting the coal will probably be 3d. to 4d. per ton extra, and road-repairing will cost at least 1d. per ton more.

It appears that, where the intervening strata exceed 6 feet in thickness, it would be more profitable to work the Pyotshaw seam first; and where the strata are 6 feet or less in thickness the Main coal should be worked first.

## II.—The Splint and Virgin Coal-seams at Auchinraith Colliery, Blantyre.

The Splint and Virgin seams are found at a depth of 888 feet below the surface.

A section of the seams and contiguous strata is as under:—

| | Ft. | In. |
|---|---|---|
| Blaes ... ... ... ... ... ... ... | — | |
| Splint Coal-seam: **COAL** ... ... ... ... | 3 | 9 |
| Blaes ... ... ... ... ... 9 inches to | 1 | 2 |
| Virgin Coal-seam: **COAL** ... ... ... ... | 2 | 4 |
| Dark fakes ... ... ... .. ... ... | — | |

Narrow roads are driven in the Virgin seam, and a thickness of 18 inches of the Splint seam is brushed down to give height in the roadways.

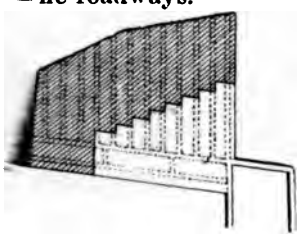

Fig. 1.—Scale, 400 Feet to 1 Inch.

When near the march or other boundary, the Virgin seam is opened into ordinary longwall, with places 36 feet wide. The holing is made in the blaes, over this seam, and the places are built and stowed with the holings and rubbish got from the roads. Occasionally débris is taken from the other seams for the purpose of stowing the places. When the boundary is reached, the Splint coal is broken into, and worked backwards, the old roads being used. The stowage of the Virgin seam makes a good holing for the Splint seam and the roof is secured as in longwall.

Fig. 1 illustrates the system of working and the Splint seam, being worked backward, is shewn by shading. The strata are quite level.

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Mr. Thomas Moodie's paper on "The Working of Contiguous, or nearly Contiguous, Seams of Coal" was read as follows:—

# THE WORKING OF CONTIGUOUS, OR NEARLY CONTIGUOUS, SEAMS OF COAL.

By THOMAS MOODIE.

## I.—The Lochgelly Splint and Parrot Seams at Little Raith Colliery, Cowdenbeath.

Little Raith colliery is situated in the parish of Auchertool in Fifeshire. The Lochgelly Splint and Parrot seams will be described. Similar coal-seams are worked at many collieries in the same district, and in some cases there is a considerable thickness of strata between the seams, varying from 6 inches to 20 feet. In the Little Raith pits, however, the seams practically touch each other—only an inconsiderable parting lying between them. The Splint coal, in many parts, had a very soft roof: blaes and ironstone-ribs being mixed, in places, with a thickness of 24 feet. For the support of this soft roof, a piece of craw-coal was left on, varying from 18 to 20 inches, above the regular working (Fig. 1, Plate XVI.).

The panel-system of working was adopted at Little Raith colliery, the panel being formed by leaving large barrier-pillars around the main roads and air-passages (Fig. 2, Plate XVI.), and inside these barriers the stoops were made of a smaller size. The barrier-pillars were formed from 100 to 130 feet square, and the openings between them were driven 9 feet wide. The barrier-pillars were made in the under leaf only, the upper leaf being left as a roof. The thickness of the upper leaf in this working varied from 4½ to 5½ feet of good splint coal. The under leaf varied from 4½ to 5¼ feet in thickness, and contained three kinds of coal, namely, 1 foot 6 inches of free coal; 2 feet of gas coal; and, below this, free coal varying from 1 foot 6 inches to 1 foot 8 inches.

The workings, in the under leaf, inside the barriers were divided into small pillars, varying from 15 to 24 feet square; the rooms, as a rule, varied from 12 to 14 feet in width; and the ends varied from 9 to 12 feet in width.

As the working proceeded in the under leaf inside the panels, signs of extra weight soon made their appearance. The small stoops began to show signs of weakness, and wood and stone pillars were built, at intervals, wherever they were found necessary: and sufficient pillars having been placed, the workings were continued in the under leaf onward to the further side of the panels.

The far side of the panel in the under leaf having been reached, the upper leaf was opened up and brought back, and worked with the same road-ways and air-ways as had served for the under leaf. This coal was well "backed" and "cracked," at intervals varying from 2 to 2½ feet, and yielded fairly good round coals.

In the working of these seams, powder was scarcely ever used. The pick, mall and wedge, were practically all that were required.

This system made good work for the men, the workings could scarcely by any possibility be blocked by fire or by falling débris, and the working expenses were kept at the minimum. For, though gob-fires were common in this seam when less suitable methods of working were attempted, there was comparative freedom from such dangers, and from the extra expenses caused by fires by the method adopted.

As soon as a panel was worked out, the openings through the barriers that formed the road-ways and air-ways were closed with brickwork; and this prevented fire or gas from the gob doing any damage to the main-roadways or airways, which were beyond the panel, and used for the working of other sections. Sometimes the under leaf was all gas-coal, the full thickness of the seam. The workings were dry, and naked lights were used throughout. The system had the defect that, the pillars left in forming the first working of the under seam being crushed by the superincumbent weight, it was impossible to get out all the coal as in other methods of working.

A systematic division of labour was carried out in these pits: drawers being employed to lift the coal from the face, and to leave empty hutches with the colliers.

Most of the coal was hand-filled: the smallest pieces were filled into the hutch with a "harp," the openings between the ribs being 1½ inches, and, when this class of coal reached the pit-bank, only a small percentage of dross was extracted while going over the coal-screen.

## II.—The Chemiss Seams, Leven Colliery, Leven.

In the preceding case, gob-fires were frequent, but in the present case, gob-fires were absent until recent years.

The Chemiss seam, 4½ feet thick, occurs at Leven in the east of Fife; adjacent and parallel to and under the Chemiss seam lies the Bink and Little coal-seam, the principal stratum being about 3½ feet thick (Fig. 3, Plate XVI.).

The lower seam was worked first on the longwall principle, leaving the upper seam as a roof for these lower workings. In the lower seam, longwall headings were run up to the rise for a distance of 600 feet. Places and road-ways were turned away at right angles every 42 feet, and the buildings or pack-walls were supplied mainly from the pavement-brushings, which varied from 1½ to 2 feet. Small pillars were built on the road-sides every 9 feet: these, for the most part, were got from broken timber in the centre of the walls and road-heads, but sometimes they were got from the pit-bank. In these workings, the men did the brushing and building of pack-walls on the sides of their own roads. When the main levels had been carried a distance of 300 feet, another longwall heading was driven to cut off the length of the branch-roads (Fig. 4, Plate XVI.). In this way, continuous working was secured.

Fig. 5 (Plate XVI.) shews a section of the workings of the Leven pit, on the panel system, where barrier-pillars are employed to protect the main ways round the section. The working of the under leaf is carried forward a distance of 600 feet or thereabouts, and then the upper leaf is worked back, the same roads being used as in the under-working.

Both leaves shewed a fair average thickness of coal. The Bink seam, at times, had a section of 3½ feet, sometimes less; the Chemiss leaf shewed 4 feet of clean coal, and the total measurement was 7½ feet. These seams gave excellent results; they were easy to work and were exceptionally good longwall workings.

These seams have at places been worked both in advancing order, the first working-face being kept about 90 feet in front of the second working-face, a system which is perhaps advisable where the roof above the upper seam is firm and strong. But simultaneous workings on the same road-way are objectionable if the roof be soft.

In the Bink and Chemiss seams most of the coals were hand-filled, as small or slack coal was not much in demand in the district. Miners and separate drawers were employed. In many parts of Fifeshire, a division of labour is approved, as being more profitable to the owners, and more agreeable to the miners. The coals were run down wheel-braes, on the cut-chain principle, to the level roads.

### III.—The Splint and Virgin Seams of Earnock Colliery, Hamilton.

The Splint and Virgin seams lie at an average depth of 870 feet. At Earnock colliery, the seams lie closely together, and have a working section of 7 feet 2 inches. The under seam is the Virgin coal, with a height of 2 feet 9 inches (Fig. 6, Plate XVI.). It is a free and clean coal of very fine quality, but it has a tendency to burst off in the centre, near the parting between it and the overlying Splint coal. This tendency is a common characteristic of the under seams in the Hamilton district, wherever two seams come closely together, and calls for great caution in working.

The workings were laid out on the stoop-and-room system, the stoops being of exceptionally large size, varying from 150 to 180 feet square (Fig. 7, Plate XVI.). The openings were driven 8 feet wide, and 5 feet high, being cut through the full height of the Virgin coal, and into 2 feet 3 inches of the Splint coal. When a sufficient area of pillars was formed, the second working was begun by splitting the large coal-blocks, sometimes into two, and sometimes into four portions. The lifts or slices from the pillars measured 9 feet or thereabouts, and where necessary, the miners were able to prop and crown these lifts with perfect safety. In these workings, very little coal was lost, and as little timber; for when the lifts had reached the edge of the pillar, nearly all the timber could be drawn. This system had been brought almost to perfection in the Hamilton district; it suited both the Virgin and Splint seams much better than any other method, and was cheaper than the longwall system.

The roof of the upper or Splint seam was sometimes very bad: consequently part of the upper coal was left on as a support for the roof, and the expense for upkeep of roads was reduced to a minimum. Except at the very point of stooping, the roads

were maintained at normal size and strength. By laying out the coal in larger blocks than was usually done, it was observed that when the strata did break in the goaf, at the point of stooping, the pillars of the coal-blocks that had been left in the rear, were of such size and strength that they were able to resist any pressure that was brought upon them, while the strata were being fractured. Consequently, the roads were maintained in good order to the very point of stooping, and they were strong and safe from side to side. The inclination of these seams varied from 1 in 6 to 1 in 12.

The miners worked about 3 tons *per diem* from the openings, and it was all done with pick, mall and wedge, no blasting being allowed either in the lower or the upper seam workings.

Drawers and ponies took away the coals from the working-face, and the empty hutches were left for the miners.

### IV.—The Main and Pyotshaw Seams of Mount Vernon Colliery, Lanarkshire.

The Main and Pyotshaw seams lie close together in some places, and in other places are separated by as much as 18 feet of strata (Fig. 8, Plate XVI.). Where the intervening strata are thick, the two seams are worked separately on the longwall system; and where the seams come close together they are worked as one seam. At the Mount Vernon collieries, these seams are separated by strata varying from ½ inch to 2 feet.

Where the intervening strata are 2 feet thick, pillars are formed in the Main coal-seam on the usual stoop-and-room system, propping up the mid stone in the openings made in the Main coal-seam. The pillars measure 100 feet square, and it is necessary to exercise great caution while stoops are being removed. The coal of this seam at these collieries is much stronger than in the Hamilton district. At the Daldowie and Kenmuirhill collieries, these seams are worked on the stoop-and-room principle, taking out the stoops in the usual way, as adopted at the Earnock colliery (Fig. 7, Plate XVI.). At Mount Vernon colliery, the same mode of working is practised where it is suitable; but, in some districts of this colliery, the Main coal is very strong, and the hardest and strongest holing is next to the pavement.

For a while, the hardness next the pavement was the despair

"...nearly Contiguous, Seams of Coal."

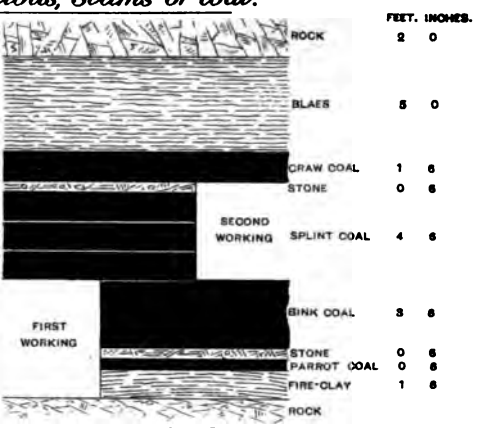


FIG. 3.—SECTION.

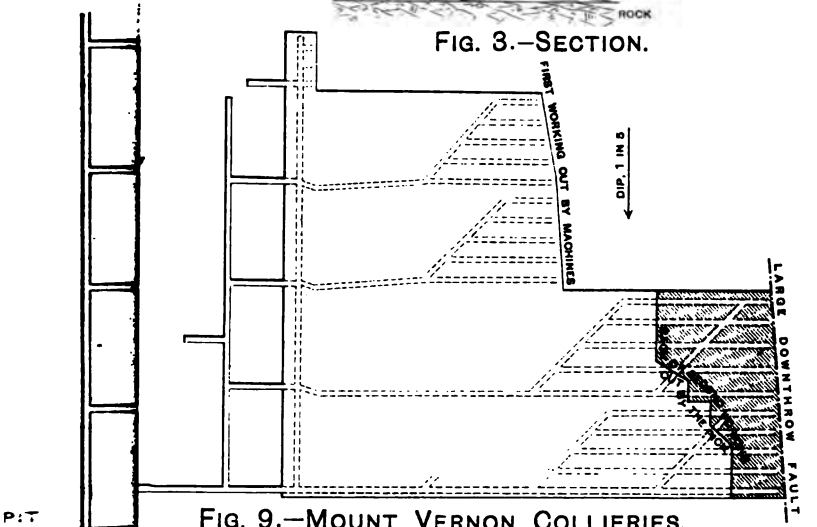


FIG. 9.—MOUNT VERNON COLLIERIES.
MAIN AND PYOTSHAW COAL-SEAMS.

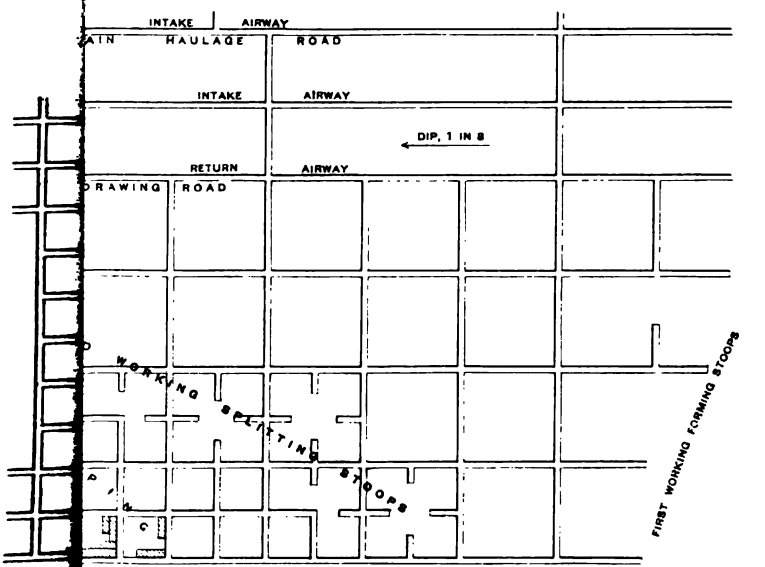


FIG. 7.—EARNOCK COLLIERY.
*SPLINT AND VIRGIN COAL-SEAMS.*

of the miners, and was a matter of great perplexity to the management, leading to the adoption of compressed-air coal-cutting machines and a change of the method of working from stoop-and-room to the longwall system. The Main coal-seam is holed with a Gillott machine, driven by compressed air. This working is entirely confined to the Main coal-seam, 3 feet thick, leaving the Pyotshaw seam for a roof (Fig. 8, Plate XVI.).

Small wooden pillars are built on each side of the roadway, every 9 feet, and 2 feet of blaes forming the roof of the Pyotshaw coal-seam is taken down. Above this blaes, there is generally sandstone-fakes or rock. Sufficient buildings are obtained for the first working, without using any of the coal.

The stripping of the faces, blasting-down of the coal, and the filling and drawing, are let to contractors, so that throughout the district, both in the stoop-and-room and longwall workings, the men at the working-faces have to dig and draw their own coal.

The method of working the Pyotshaw seam and forming the roadways is as follows: One level-road is maintained, and from this main road, four others branch out; then another main road is driven, and from this another set of four branch-roads are run out. The main roads are brushed for the use of ponies, and the branch-roads are only once brushed. In this way, there are ten walls or 420 feet of face, which is a fair length for one machine to cut in each shift, and when one machine-cut approaches the specified distance in the field, another machine begins to follow it. The roads, which were formed in the first working, are suitable for bringing back the Pyotshaw seam in the second working, and this is done without any further building in the second working.

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Mr. Thomas Arnott's paper on "The Working of Contiguous, or nearly Contiguous, Seams of Coal" was read as follows:—

# THE WORKING OF CONTIGUOUS, OR NEARLY CONTIGUOUS, SEAMS OF COAL.

By THOMAS ARNOTT.

## The Virgin and Splint Coal-seams at Newton Colliery.

The plan (Fig. 1, Plate XVII.) shows, by shading, the area of workings, in the Virgin seam, where the waste of the Splint seam overlays the top of the coal, and the section (Fig. 2, Plate XVII.) shews the strata lying between the two seams under ordinary circumstances (Table I.) and where the two seams run together (Table II.).

Table I.—Section of Splint and Virgin Coal-seams.

| | Ft. | In. |
|---|---|---|
| Rock ... ... ... ... ... ... ... | — | |
| Blaes and rock-ribs ... ... ... ... ... | 9 | 0 |
| Splint Coal-seam: **COAL**, 2 feet 9 inches to | 3 | 0 |
| Daugh, *nil* to ... ... ... ... ... ... | 0 | 9 |
| Strata ... ... ... ... ... ... ... | 9 | 0 |
| Virgin Coal-seam: **COAL** ... ... ... | 2 | 0 |
| Fire-clay ... ... ... ... ... ... | — | |

Table II.—Section of Splint and Virgin Coal-seams.

| | Ft | In. |
|---|---|---|
| Rock ... ... ... ... ... ... ... | — | |
| Blaes and rock-ribs ... ... ... ... ... | 12 | 0 |
| Splint Coal-seam: **COAL**, 2 feet 9 inches to | 4 | 0 |
| Virgin Coal-seam: **COAL**, 2 feet to ... ... | 2 | 8 |

The Splint coal-seam, throughout the field, under normal conditions, varies in thickness from 2 feet 9 inches to 3 feet, and where the two seams are wrought together, it varies from 2 feet 9 inches to 4 feet in thickness; and the soft strata above the Splint coal-seam also thicken from 9 feet to 12 feet.

The Virgin coal-seam, immediately underlying the waste of the Splint coal-seam, varies in thickness from the normal, 2 feet, to 2 feet 8 inches, and is found to be "sagged" and harder to

be worked than when the ordinary thickness of strata lies between it and the waste of the Splint coal-seam, but the coal, when gotten was of larger size.

The depth from the surface to the Virgin coal-seam is about 1,030 feet.

The brushing of the common roads in the Virgin coal-seam, where it and the waste of the Splint coal-seam lie together (except where old roads in the Splint seam were crossed), was in the old waste and first carry of the brushing in the Splint seam; and in main roads and where old roads in the waste of the Splint seam were crossed, the brushing was taken nearly up to the rock lying above the Splint seam.

This abnormal proximity of the two seams has been proved in the Splint seam for a length of 3,000 feet in the direction of the dip and rise, and for an average width of about 330 feet. It will be observed (Fig. 1, Plate XVII.) that the level course also changes.

When the two seams were first found together, a small district was opened out on the longwall method, working both seams, but it was soon found that this method could not be continued owing to the soft nature of the roof lying above the Splint seam. Consequently the working of the Virgin seam was stopped, and the working of the Splint seam, alone, was continued on the top of it. Table III. contains a section of the seams at this place.

TABLE III.—SECTION OF SPLINT AND VIRGIN COAL-SEAMS.

| | | Ft. | In. | Ft. | In. |
|---|---|---|---|---|---|
| Rock | | | | — | |
| Blaes and rock-ribs, 9 feet to | | | | 12 | 0 |
| Splint Coal-seam: | COAL | 1 | 8 | | |
| | PARROT COAL | 0 | 3½ | | |
| | COAL | 1 | 9 | | |
| | | — | — | 3 | 8½ |
| Dirt | | | | 0 | 6 |
| Virgin Coal-seam: | COAL | | | 2 | 4 |
| Fire-clay | | | | — | |

In another isolated area, where the two seams occurred together, the Virgin seam was worked first, on the longwall system, and workings in it were continued until the two seams were separated by about 6 feet of blaes, and then the workings in the Virgin seam were stopped. The Splint seam was then

opened out at a point, 130 feet back from the working-face in the Virgin seam, and the working was continued over the waste and unwrought coal of the Virgin seam, until the boundary of the field was reached. The portion of the Splint seam which had been left to form a roof to the Virgin seam was then worked back from the old roadways in the Virgin seam.

Where two seams, similar to those above described, occur together in a sufficiently large area, it would be the best method of working to take out the lower seam first; but no difficulty has been experienced in working the Virgin seam after the Splint seam has been all extracted.

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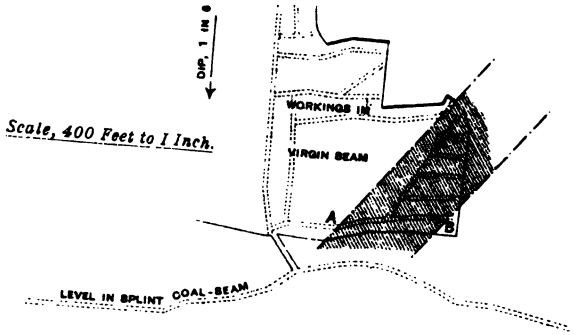
Mr. RICHARD KIRKBY's paper on "The Dysart, Wemyss and Leven Coal-field, Fifeshire," was read as follows:—

The Institution of Mining Engineers.
Transactions 1901-1902.



## To illustrate Mr. T. Arnold's Paper on "The Working of Contiguous or nearly Contiguous Seams of Coal."




Scale, 400 Feet to 1 Inch.

FIG. 1.—PLAN.

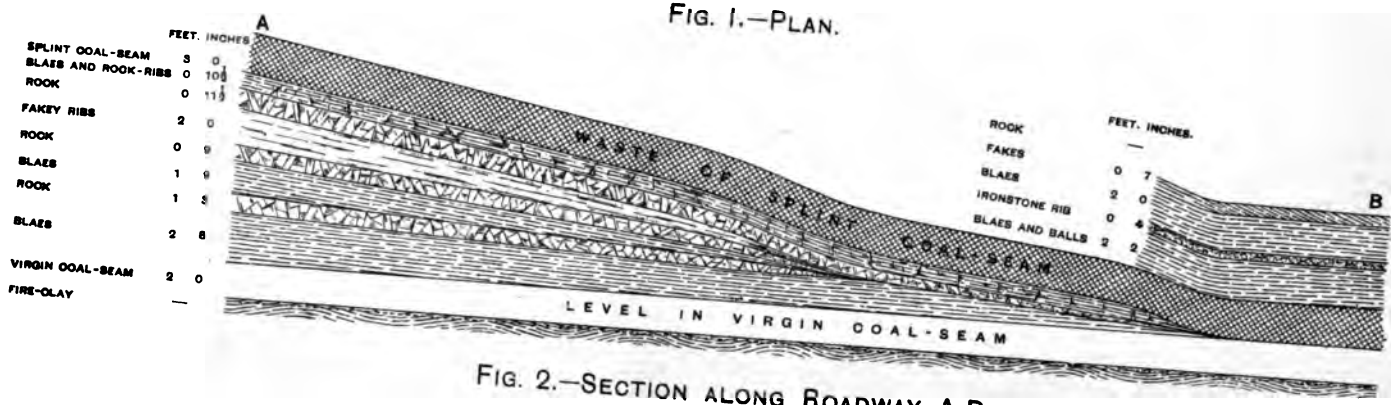



FIG. 2.—SECTION ALONG ROADWAY A B IN FIG. 1.

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Horizontal Scale, 40 Feet to 1 Inch

# THE DYSART, WEMYSS AND LEVEN COAL-FIELD, FIFESHIRE.

By RICHARD KIRKBY.

## Introduction.

The above name is given to this coal-field by Sir Archibald Geikie in his memoir on the geology of Fifeshire. It is in the Coal-measures, and these are sometimes called the true Coal-measures in order to distinguish the series from the Carboniferous Limestone-measures, which really contain the best coals of the Carboniferous system in Fife; and with the exception of a small patch at Kinglassie, this field is the only one in Fife in the Coal-measures. The surface area of the field is about 12 square miles, and the measures dip southeastward under the Firth of Forth, but the extent in that direction is not known.

## Boundaries (Fig. 1, Plate XVIII.).

The Seven-feet, the lowest workable seam, crops out on the sea-coast a little to the west of the town of Dysart. The outcrops of this coal and of the Dysart Main seam, the next one above it, have been traced inland in a northerly course for over 5 miles. This line may be said to form the western boundary of the coal-field. The actual boundary, on the south, is not known, as it lies beneath the Firth of Forth. The distance along the coast-line to the eastern extremity at Largo is about 9 miles, but the practical working-boundary is about 1 mile nearer Leven. A line drawn from the eastern extremity to Markinch, may be said to define the northern boundary of the field. It will be recognized (Fig. 1, Plate XVIII.) that the coal-field is cut off on that side by a series of faults throwing out the seams to the north.

## Thickness (Fig. 2, Plate XIX.).

The Coal-measures in Fife are divided into the Upper Red beds and the Lower beds. The former are barren of workable

coals, and the Lower beds contain the only workable seams. According to the *Vertical Sections of Fife*, issued by the Geological Survey, the total thickness of the Coal-measures is nearly 3,000 feet. With more recent information at his disposal, the writer is inclined to think that this estimate is too high.

It should be mentioned that the actual top of the Red beds cannot be seen, but the writer's father (the late Mr. J. W. Kirkby) shewed that the highest visible bed—a red and purplish sandstone—is seen at low-water mark near the mouth of the river Leven. From information obtained by levelling the dip-workings in the Chemiss coal-seam in Leven colliery, this red sandstone appears to occur about 1,200 feet above that seam: and according to sections taken in the shafts of Leven colliery, 760 feet of these beds are Upper Red beds. Now, it is fairly certain that the depth at Leven from the Chemiss coal-seam to the Seven-feet coal-seam will not exceed 840 feet: to this may be added 150 feet for the thickness of the strata lying between the Seven-feet seam and the Millstone Grit, and we obtain a total thickness for the Coal-measures of 2,190 feet—say 2,200 feet, or 760 feet of Upper Red beds and 1,440 feet of Lower beds, at the eastern end of the field.

The thickness at the western end is somewhat greater. The Red beds may be reckoned of the same thickness as at Leven; adding to their thickness, the section as found in the Wemyss district, namely about 1,470 feet from the bottom of the Red beds to the Seven-feet seam, and 150 feet more to the top of the Millstone Grit, makes a total of about 2,400 feet. The vertical sections (Fig. 3, Plate XIX.) suggest that another 150 feet could be added, by taking the Dysart section into account.

It may be mentioned that there is no unconformity between the Upper Red and the Lower beds. It would be extremely interesting to know how much farther the Upper Red beds continue dipping under the sea, and whether Permian measures occur in the bed of the Firth of Forth.

### Faults (Fig. 1, Plate XVIII.).

The principal faults run in an east-and-west direction, but one, in the west of the field, lies nearly north-and-south. As proved in the workings of the Dysart collieries, it runs from a point a little to the south of the Frances pit to a point about

1,500 feet due east of the Randolph pit, where it dies out; but from this point, an anticline appears to run in a northerly direction. The dotted line on the map shews the approximate position of the crown of this anticline. The line of "level course" in the Dysart Main seam in the Randolph pit is also shewn on the map.

There is a trough or syncline on the west, about 3 miles long from north to south, and about 1 mile broad: Balgonie colliery and the Randolph pit are in this trough. The Dysart Main coal-seam crops out on both the western and the eastern sides of the trough towards Balgonie, but on the eastern side of the Randolph pit, the outcrop is saved by the greater depth. At E (Fig. 1, Plate XVIII.), the depth to the Dysart Main seam is about 210 feet.

The cross-sections (Figs. 9 and 10, Plate XX.), along the lines ABC and DEF, explain the occurrence of the anticline and of the syncline.

As already mentioned, the five principal faults lie in an east-and-west direction and run parallel to each other: (1) The Buckhaven hitch is seen in Denbeath colliery, with an upthrow to the north of 600 feet; near Muiredge colliery, the throw is reduced to 390 feet. It runs between Wellsgreen and Rosie collieries, and has been got in the Lady Lilian colliery-workings; and it dies out before reaching the ridge or anticline.

(2) The Muiredge hitch lies about 2,400 feet north of the Buckhaven hitch, and its upthrow is also to the north. Between Methil and the mouth of the river Leven, the throw is 96 feet; about 1½ miles inland it increases to 300 feet: but farther westward it again decreases, the throw between the Cameron and Wellsgreen collieries being only 90 feet. It evidently does not die out entirely until it reaches the workings of Balgonie colliery to the north of Thornton junction.

(3) The Kirkland hitch is the next of importance, with an upthrow to the north, but the amount of displacement along the whole of its course is not definitely known. In the old workings in the Chemiss seam at Kirkland, the throw was said to be 132 feet, but where it runs into Leven colliery-workings it does not exceed 30 feet, where proved, and it spreads out and dies away to the dip. To the west of Kirkland, it was touched by the level in the Parrot seam from Pirnie pit, and as a considerable quantity of water was obtained the hitch was not proved.

(4) The next fault separates the Durie coal-field from Leven, and has a greater upthrow than any of those yet described—the amount being about 840 feet to the north.

(5) The next and last fault that need be mentioned, forms the northern boundary of the Durie field, and according to the Geological Survey map, the upthrow would be about 1,500 feet to the north. This hitch appears to trend a little to the south in going eastwards, and it and the previously mentioned fault will probably run into one, a few miles to the east. It is certain that it lies to the south of Lundin Links railway-station and runs to the north of the harbour at Largo, because a little to the west of the harbour the Ochre beds and marls which lie above the Eight-feet coal-seam are seen, and the position of the Eight-feet seam, and the two seams below should be somewhere about Lundin Mill. However, these seams cannot have a long run inland, as there is another big fault just to the north of the bridge over the Hatton burn at Lundin Mill. This hitch brings up the Carboniferous Limestone series.

The smaller hitches and troubles, as a rule, all lie in the same direction as the larger ones, and the upthrow is nearly always to the north.

## Workable Coal-seams.

There are nine coal-seams which are either at present being worked, or have been worked at some former time. Taking each seam at its average thickness through the field, the total thickness of saleable coal is about 45 feet, including gas, steam and household coals.

*Seven-feet Seam.*—The Seven-feet or Dysart Lower and lowest coal-seam, has not been worked to any considerable extent for a number of years, but it will probably be broken into again when some of the better coals become exhausted. It was worked formerly at Dysart, Wemyss and Balgonie, more for the sake of the ironstone-bands in the shale above the seam than for the coal itself.

It was recently won by a mine in Wellsgreen colliery, but it was considered to be hardly a paying subject, and nothing is being done in it at present. The section was as follows:—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Shale with ironstone-bands ... . | — | | | |
| | Black shale ... ... ... ... | 1 | 6 | | |
| | Hard fire-clay ... ... ... ... | 1 | 0 | | |
| | | -- | | 2 | 6 |
| *Seam:* | **COAL** ... ... ... ... ... | 0 | 10 | | |
| | Stone ... ... ... ... ... | 0 | 5 | | |
| | **COAL**, clean except for ribs of pyrites | 2 | 3 | | |
| | Fire-clay ... ... ... .. | 0 | 9 | | |
| | **COAL**, rather brassy ... ... .. | 1 | 4 | | |
| | Stone ... ... ... ... ... | 0 | 7 | | |
| | **COAL** ... ... .. ... ... | 0 | 11 | | |
| | **COAL**, slaty ... ... .. ... | 0 | 8 | | |
| | Stone ... ... ... ... ... | 0 | 1 | | |
| | **COAL** ... ... .. ... ... | 0 | 3 | | |
| | | | | 8 | 1 |
| *Thill:* | Fire-clay ... ... ... ... ... | | | — | |

The coal is rather poor, containing iron-pyrites. It is also considerably laminated with mineral charcoal, which makes it dusty when brought to the pit-head. The ironstone-bands or ribs do not appear to be worth working at Wellsgreen.

This seam has quite recently been got, in a crosscut mine in the Lady Lilian pit, of the following section:—

| | | Ft | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Shale and ironstone-bands ... ... | — | | 5 | 0 |
| *Seam:* | **COAL** ... ... ... ... ... | 0 | 10 | | |
| | Stone ... ... ... ... ... | 0 | 2 | | |
| | **COAL** ... ... ... ... ... | 2 | 0 | | |
| | Fire-clay ... ... ... ... ... | 0 | 6 | | |
| | Shale and ironstone-band ... ... | 1 | 0 | | |
| | **COAL** ... ... ... ... ... | 1 | 8 | | |
| | Stone ... ... ... ... .. | 0 | 4 | | |
| | **PARROT COAL** ... ... | 0 | 4 | | |
| | **COAL** ... ... ... ... ... | 1 | 5 | | |
| | Stone ... ... ... ... .. | 0 | 3 | | |
| | **COAL** ... ... ... ... ... | 1 | 4 | | |
| | | -- | — | 9 | 10 |
| *Thill:* | Fire-clay ... ... ... ... | -- | | — | |

The quality appears to be similar to that at Wellsgreen.

The Frances pit, Dysart, has been sunk recently through the Seven-feet seam, yielding the following section: the occurrence of parrot-coal in the seam is very interesting:—

| | Ft. | Ins. |
|---|---|---|
| Shale ... ... ... ... ... ... | — | |
| Ironstone-rib ... ... ... ... . | 1 | 0 |
| Shale ... ... ... .. ... . | 1 | 0 |
| **COAL** ... ... ... ... ... ... | 3 | 9 |
| Shale ... ... ... ... ... . | 3 | 0 |

| | Ft. | Ins. |
|---|---|---|
| COAL ... ... ... ... ... ... | 2 | 9 |
| PARROT COAL ... ... ... ... | 0 | 3 |
| Hard stone ... ... ... ... ... | 0 | 10 |
| PARROT COAL, good ... ... ... | 0 | 11 |
| COAL, with rib, 1¼ inches thick in centre | 3 | 0 |
| Hard stone ... ... ... ... ... | 0 | 8 |
| COAL ... ... ... ... ... ... | 0 | 6 |
| Thin rib ... ... ... ... ... | — | |
| COAL, with thin rib ... ... ... | 2 | 2 |
| Dark strong shale ... ... ... ... | — | |

The Seven-feet coal-seam has always been considered to be the lowest seam of the Coal-measures, but a coal which, so far as the writer is aware, has never hitherto been seen, has been found in the Frances pit at a depth of 225 feet below the Seven-feet seam, of the following section:—

| | Ft. | Ins. |
|---|---|---|
| COAL ... ... ... ... ... ... | 1 | 8 |
| Stone ... ... ... ... . ... | 0 | 3 |
| COAL ... ... ... ... ... ... | 1 | 7 |
| Stone ... ... ... ... ... ... | 0 | 6 |
| COAL ... ... ... ... ... ... | 1 | 10 |
| Fire-clay ... ... ... ... ... | — | |

*Dysart Main Seam.*—This seam lies from 60 to 70 feet above the Seven-feet seam and is the thickest seam in Fife, of any occurring either in the true Coal-measures or in the Limestone-measures. It attains its greatest thickness at Dysart and West Wemyss, and thins eastward (Fig. 12, Plate XX.).

The Roof coal, which varies from 4½ feet in thickness at Dysart to 2 feet in Cameron colliery, is not workable. The Coal Thief, which forms the bottom portion of the seam, is 5 feet 9 inches thick in Dysart, and runs out to nothing to the east. This division has never been worked until quite recently, in the Victoria pit. The other portions of the seam, all thin out individually. The Myslen coal and stone present a particularly interesting illustration of this thinning-out.

The seam is worked in the Dysart collieries by the stoop-and-room system in two or three lifts. Elsewhere it is taken out by longwall. The following section and sketch (Fig. 4, Plate XVIII.) shews how the seam is being worked in the Victoria pit, in four leaves:—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Blaes or shale ... ... ... | -- | | | |
| | Roof COAL ... ... ... | 4 | 0 | | |
| | | | | 4 | 0 |
| *No. 4 Leaf:* | Spar COAL ... ... ... | 1 | 7 | | |
| | Stone ... ... ... ... | 0 | 2 | | |
| | Toughs COAL ... ... ... | 2 | 1 | | |
| | | | | 3 | 10 |
| *No. 3 Leaf:* | Clears COAL ... ... ... | 1 | 8 | | |
| | Mys'en: stone ... ... ... | 0 | 5 | | |
| | COAL ... ... ... | 0 | 11 | | |
| | stone ... ... ... | 0 | 4 | | |
| | Nethers COAL ... ... ... | 2 | 8 | | |
| | | | | 6 | 0 |
| *No. 2 Leaf:* | Clears COAL, holing ... ... | 0 | 11 | | |
| | Parting ... ... ... ... | 0 | 2 | | |
| | Grounds COAL ... ... ... | 3 | 10 | | |
| | Thief stone ... ... ... | 1 | 3 | | |
| | | | | 6 | 2 |
| *No. 1 Leaf:* | COAL Thief ... ... ... | 5 | 5 | | |
| | Sandy shale ... ... ... | 1 | 2 | | |
| | Sclitty COAL, holing ... ... | 1 | 4 | | |
| | | | | 7 | 11 |
| *Thill:* | Fire-clay ... ... ... ... | — | | — | |

The Coal Thief was not worked formerly, and the remainder of the seam was taken out in two workings, the first working extending to the top of the Myslen stone; and when the section or district was worked out in the bottom coal, the top coal (Clears, Toughs and Spar coals) was worked back in an opposite direction. This method of working is adopted in the eastern workings of the Lady Lilian pit, and in Wellsgreen and Balgonie collieries. In the Cameron colliery, as a rule, only the Grounds, Nethers and Clears (above the Myslen) coals are worked, and this thickness is taken out in one operation, being only about 5½ feet.

The Dysart Main coal-seam is very liable to spontaneous combustion, and both Dysart and Wemyss collieries have been much troubled by it. Many acres of coal have been lost and much time and money spent in digging out or building off gob-fires.

The section of the seam at Balgonie is very similar to that at Wellsgreen. There have been fires in the former colliery, but not recently. Wellsgreen colliery has been free from them, and once or twice only has there been a slight heating in the waste, but a little extra air soon cooled the place, and very shortly afterwards the waste was filled by the heaving of the fire-clay pavement. The writer is sure that it is only owing to the waste in

Wellsgreen colliery being well filled with fire-clay and stone, and to the soft nature of the pavement, that the colliery has been free from spontaneous fires. The same remark also applies to the Cameron colliery.

In Wemyss colliery, on the other hand, it will be understood that owing to the Coal Thief and stone being left, the pavement had no chance of heaving, and there is very little dirt for stowing the waste. But now it is anticipated that the new system of working in three and in four leaves will so stow the waste that there will be no more fires.

The whole of the workable coal in the Dysart Main seam is sold for steam purposes, as it is a free-burning coal of very good heating power, and is very free from pyrites.

The fire-clay below the coal and the blaes or shale above it, make good bricks.

The seam is at present being worked from the following pits, namely:—Dysart colliery, four shafts; Wemyss colliery, two shafts; Balgonie colliery, two shafts; Wellsgreen colliery, one shaft; and Cameron colliery, one shaft.

*Sandwell, etc., Seams.*—The Sandwell coal, 2½ feet thick, occurs 84 feet above the Dysart Main seam. The Coal More seam, 2½ feet thick, is 39 feet above the Sandwell seam; and the Branxton coal, 3 feet thick, lies 24 feet above the Coal More seam. None of these seams are worked.

*Bowhouse Seam.*—This coal lies about 78 feet above the Branxton seam, and 420 feet above the Dysart Main seam at Wemyss. At Dysart, in the Frances pit, this coal occurs 510 feet above the Dysart Main seam.

The seam is now being worked from Bowhouse mine at the Lady Lilian pit and at the Lady pit, West Wemyss, yielding the following section (Fig. 5, Plate XVIII.):—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Blaes ... ... ... ... ... | 2 | 0 | | |
| | Fakes ... ... ... ... ... | 1 | 0 | | |
| | | | | 3 | 0 |
| *Seam: Upper Working* – | | | | | |
| | COAL ... ... ... ... | 0 | 6 | | |
| | Fakes ... ... ... ... | 0 | 5 | | |
| | COAL ... ... ... ... | 2 | 7 | | |
| | | | | 3 | 6 |

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Lower Working*— | | | | | |
| | COAL ... ... ... ... | 2 | 5 | | |
| | Stone ... ... ... ... ... | 0 | 2 | | |
| | COAL ... ... ... ... | 2 | 2 | | |
| | Sclitty COAL ... ... ... | 1 | 3 | | |
| | Fire-clay, holing ... ... ... | 0 | 3 | | |
| | | | | 6 | 3 |
| *Thill:* | Hard stone ... ... ... ... | — | | — | |

In the mine at the Lady Lilian pit, the seam is a little thinner, there being only 5½ feet of workable coal. The quality of the coal is somewhat similar to that of the Dysart Main seam, and it is all sold for steam-coal.

This seam appears to thin out very suddenly, as it is only represented by about 6 inches of coal in the section of the Wellsgreen shaft, and it is not seen at Balgonie. In a bore-hole from the bottom of the Michael pit, Wemyss, it is found of full thickness and a mine has been commenced there to win it.

*Earl David's Parrot.*—This seam lies about 66 feet above the Bowhouse seam. The following is the section at West Wemyss:—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Shale ... ... ... ... ... | — | | — | |
| *Seam:* | PARROT COAL ... ... ... | 1 | 2 | | |
| | COAL ... ... ... ... .. | 1 | 2 | | |
| | | | | 2 | 4 |
| *Thill:* | Fire-clay ... ... ... ... | — | | — | |

The Fife Coal Company, Limited, put down some bore-holes, about ½ mile northward of the Lady Lilian pit, and a trial-hole proved this seam. The parrot-coal varied from 1 foot 2 inches to 1 foot 10 inches in thickness, but there was only 2 inches of black coal below it. These bore-holes were made near the outcrop of the seam. A few tons of parrot-coal were taken out of the trial-hole, and a sample when analysed gave 8,300 cubic feet of 33 candlepower gas. About 3,000 feet to the dip, from that point, the seam changed into 18 inches of black coal with no sign of any parrot-coal. Near Pirnie old pit, it was also black coal. The Earl David's parrot-coal is not worked at present.

*Wood Coal.*—This seam is found about 54 feet above the last-described seam. The average thickness is 3 feet, but it is thicker where seen on the south side of the Buckhaven hitch in Wellsgreen colliery, and has the following section (Fig. 6, Plate XVIII.):—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Fire-clay and bands ... ... ... | — | | | |
| | **COAL** ... ... ... ... ... | 0 | 5 | | |
| | Dark fire-clay ... ... ... ... | 1 | 1 | | |
| | | | | 1 | 6 |
| *Seam:* | **COAL**, with partings of iron-pyrites | 1 | 2 | | |
| | Stone ... ... ... ... ... | 0 | 6 | | |
| | **COAL**, clean ... ... ... ... | 3 | 4 | | |
| | Fire-clay, soft ... ... ... ... | 0 | 6 | | |
| | **COAL**, with partings of iron-pyrites | 1 | 0 | | |
| | | | | 6 | 6 |
| *Thill:* | Sandy fire-clay ... ... ... ... | — | | | |

In the section of the Wellsgreen shaft, the Wood coal is 3 feet thick, the seam being all in one piece. At West Wemyss, the thickness varies from 2 feet 10 inches to 3 feet.

In a diamond bore-hole, made from the bottom of the Michael pit, the Wood coal has the following section:—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Shale ... ... ... ... ... | — | | | |
| *Seam:* | **COAL** ... ... ... ... ... | 0 | 11 | | |
| | Shale ... ... ... ... ... | 1 | 6 | | |
| | **COAL** ... ... ... ... ... | 3 | 0 | | |
| | Parting ... ... ... ... ... | 0 | 2 | | |
| | **COAL** ... ... ... ... ... | 2 | 6 | | |
| | | | | 8 | 1 |
| *Thill:* | Shale ... ... ... ... ... | — | | — | |

The coal was at one time worked in Pirnie colliery for engine coal, and the thickness varies from 2 feet 10 inches to 3 feet. The Wood coal is not being worked at the present time.

*Wemyss Parrot.*—This coal lies about 36 feet above the Wood coal. This is a capital cannel-coal, and occurs at its best at West Wemyss where it used to be worked, but has not been for some years. It has the following section:—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Shale ... ... ... ... ... | — | | — | |
| *Seam:* | Rhums ... ... ... ... ... | 0 | 4 | | |
| | **PARROT COAL** ... ... ... | 0 | 5 | | |
| | Rhums ... ... ... ... ... | 0 | 4 | | |
| | Ironstone ... ... ... ... ... | 0 | 2 | | |
| | **PARROT COAL** ... ... ... | 2 | 0 | | |
| | Brown stone ... ... ... ... | 1 | 0 | | |
| | **COAL** ... ... ... ... ... | 0 | 3 | | |
| | | | | 4 | 6 |
| *Thill:* | Shale ... ... ... ... ... | — | | | |

The above section contain 2 feet 5 inches of workable cannel. "Rhums" is the local name for a kind of black shale or foul

parrot-coal. This cannel at West Wemyss was so tough, and of such good quality, that it was the custom to carve such objects as tables and ornaments out of it.

At Pirnie colliery, where this seam has been worked for over 60 years, and contains two or three different qualities, the section is as follows:—

| | | Ft | Ins | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Fire-clay and bands ... ... ... | 5 | 0 | 5 | 0 |
| *Seam:* | Rhums ... ... ... ... ... | 1 | 3 | | |
| | Head COAL, parrot .. .. ... | 1 | 2 | | |
| | Brown stone ... ... ... ... | 0 | 6 | | |
| | Brown COAL, best parrot ... ... | 0 | 6 | | |
| | Upper Bottoms, second quality of PARROT COAL ... ... ... | 0 | 7 | | |
| | Grey stone ... ... ... .. | 0 | 4 | | |
| | Chips, PARROT COAL ... ... | 0 | 4 | | |
| | Foul PARROT COAL ... ... | 0 | 3 | | |
| | | | | 4 | 11 |
| *Thill:* | Fire-clay .. ... ... ... ... | | | | |

The Brown coal is a first rate cannel, the Upper Bottom coal is nearly as good, and both have a brown streak when scratched. The Head coal is not quite so rich and has a blacker streak. Average samples from the whole of the seam give 14,000 cubic feet of gas of 30 to 35 candlepower.

The Brown stone contains a considerable amount of oil, and at one time was taken to Methil and distilled, yielding 36 gallons of crude oil per ton, of a specific gravity of 0·871 at 60° Fahr.

At Muiredge and Wellsgreen collieries, where this seam is worked, the section is the same as at Pirnie.

This seam at Pirnie colliery thins out so much to the north-east that it is unworkable beyond a line, which may be drawn from a point 1,200 feet north of Pirnie shaft to the coast near Methil dock. The seam also thins towards the outcrop and westward.

Many fossil remains of fishes and reptiles occur throughout the whole seam, but most frequently in the Brown stone. The late Mr. J. W. Kirkby collected, and described from time to time many specimens.

About 78 feet above the Parrot seam, there is an unnamed coarse coal, 3 to 3½ feet thick, which is not worked.

*Bush Coal.*—This seam lies about 300 feet above the Parrot coal. It varies from 2½ to 3 feet, and has only been worked to a small extent.

*Chemiss Coal.*—This seam lies about 60 feet above the Bush coal, and 360 feet above the Parrot coal. Leaving the latter seam out of account, the Chemiss coal is the most valuable one in the Fife Coal-measures. It is a thick seam and is made up of four different leaves. The top portion is not worked, the next piece is a splendid house-coal, and the two lower portions are steam-coals. The seam is usually worked in two portions. In the Michael pit, the section is as follows (Fig. 7, Plate XVIII.):—

| | | Ft. Ins. | Ft. Ins. |
|---|---|---|---|
| *Roof:* | Blaes, 10 inches to ... ... ... | 1 6 | |
| | Crow COAL ... ... ... ... | 2 0 | |
| | | —— | 3 6 |
| *Seam:* | *Upper working*— | | |
| | Stone ... ... ... ... | 0 5 | |
| | Cherry COAL ... .. ... | 1 4 | |
| | Splint COAL ... ... ... | 2 8 | |
| | | —— | 4 5 |
| | *Lower working*— | | |
| | Clear COAL, holing ... ... | 1 0 | |
| | Parting ... ... ... ... | 0 1 | |
| | Bink COAL ... ... ... | 3 6 | |
| | Ironstone ... ... ... ... | 0 3 | |
| | Blaes... ... ... ... ... | 0 8 | |
| | COAL ... ... ... ... | 0 3 | |
| | | —— | 5 9 |
| *Thill:* | Fakey sandstone ... ... ... | — | — |

In the above section, the lowest coal of the seam is very thin, only 3 inches, but as a rule it varies from 1 foot to 1½ feet.

The sections (Fig. 13, Plate XX.) shew how this coal thins out to the eastward.

In the working of the two portions, the top section is worked or dropped about 60 feet behind the face of the workings in the lower or Bink coal.

In Leven colliery, when the face of the Bink coal is far enough advanced, the men are transferred to the upper leaf, which is worked about 30 feet in and then allowed to stand again.

Not only does the seam itself change, but the character of its roof alters greatly, sometimes within a few hundred feet, and in place of blaes or shale on the top of the coal, sandstone frequently comes in.

The following is a section of the seam in Leven colliery about 3,000 feet west of the shafts (Fig. 8, Plate XVIII.):—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Rock ... ... ... ... ... | — | | | |
| | Crow COAL, not worked ... ... | 2 | 0 | | |
| | | | | 2 | 0 |
| *Seam: Upper working:* | | | | | |
| | Stone ... ... ... ... | 0 | 2½ | | |
| | Splint COAL ... ... ... | 3 | 6 | | |
| | | | | 3 | 8½ |
| | *Lower working:* | | | | |
| | Parting ... ... ... ... | 0 | 1 | | |
| | Bink COAL ... ... ... | 2 | 9 | | |
| | Stone ... ... ... ... | 0 | 7 | | |
| | Little Splint COAL ... ... | 2 | 0 | | |
| | Fire-clay, holing ... ... | 0 | 4 | | |
| | | | | 5 | 9 |
| *Thill:* | Fire-clay ... ... ... ... | — | | — | |

The thickness decreases and the quality deteriorates eastward to such an extent, that only the splint portion of the seam is worth working in the greater part of the field to the east or north-east of the Leven pits. Near the 840 feet fault, the Splint coal is 3 feet thick, the Bink coal 2 feet, and the Little Splint coal only 10 inches.

In the Durie field, only the Splint coal was worth working. It was a hard coal of very fair quality, and is now all worked out.

The Chemiss seam is very much subject to "wants," which in some cases appear to be, really, very flat hitches or thrusts. Sometimes the coal is never entirely lost, but each portion of the seam is represented by about 3 inches of coal, while the partings usually thicken out to about 6 inches. Fig. 14 (Plate XX.) is a rough sketch of a "want" as it sometimes occurs and one that is easy to follow; but, unfortunately, they are not all like it. Very often the roof and the pavement meet and no sign of coal is left, and one has to drive on very much in the dark.

This seam takes fire spontaneously like the Dysart Main seam; some very troublesome fires have taken place in Leven colliery, and one or two, the writer believes, in Rosie colliery.

*Den Coal.*—This seam, in the Wemyss district, lies about 120 feet above the Chemiss seam, and in the Leven district the distance is only about 42 feet. It varies from 2 feet to 2½ feet in thickness, and is not worked.

*Six-feet Seam.*—About 48 feet above the Den coal at Wemyss is the Lower Coxtool coal, which is separated from the Upper Cox-

tool seam by 15 feet of fire-clay and shale. These two seams run together in an easterly direction, and at Muiredge colliery, where there is a bed of fire-clay only 2 feet thick between them, the combined seam is called the Six-feet, a name which holds good to the east. At Leven colliery, the parting is only 7 inches thick. At Wemyss, the Upper and Lower Coxtool seams are 2¼ and 3 feet thick respectively. The Lower seam used to be worked near East Newton, but nothing is being done in either of the seams at present at the Wemyss end of the field.

The Six-feet seam is being worked in Leven colliery, and has the following section (Fig. 15, Plate XX.):—

| | | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|---|
| *Roof:* | Blaes ... ... ... ... ... | — | | | |
| | Black shale ... ... ... ... | 0 | 10 | | |
| | | | | 0 | 10 |
| *Seam:* | **COAL** ... ... ... ... ... | 1 | 8 | | |
| | Stone ... ... ... ... ... | 0 | 7 | | |
| | **COAL** ... ... ... ... .. | 2 | 4 | | |
| | Fire-clay, holing ... ... ... | 0 | 3 | | |
| | | | | 4 | 10 |
| *Thill:* | Fire-clay ... ... ... ... | — | | — | |

The black shale, lying immediately above the coal, contains a few fishes' teeth. The coal is very bright and clear, and is shipped as steam-coal.

This seam increases a little in its thickness towards the east. In Durie colliery, the section is as follows:—

| | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|
| **COAL** ... ... ... ... ... | 1 | 6 | | |
| Stone ... ... ... ... ... | 0 | 6 | | |
| **COAL** .. ... ... ... ... | 3 | 4 | | |
| Fire-clay ... ... ... ... | 0 | 3 | | |
| **COAL** ... ... ... ... ... ... | 0 | 11 | | |
| | | | 6 | 6 |

This coal is worked only in Muiredge and Leven collieries and to a small extent in Durie colliery, at present. This is the only seam in the coal-field in which a coal-cutter had been tried. It did fairly well, but it is not working meantime, as the section of coal in which it worked has been cut off by troubles.

*Barncraig Seam.*—The next seam is called the Barncraig at the Wemyss end of the field, and the Eight-feet coal in the Muiredge and Leven district.

In the Michael pit, it occurs 60 feet above the Upper Coxtool seam, and 258 feet above the Chemiss seam; but at Leven it is

only 144 feet above the latter and 42 feet above the Six-feet coal. In Durie colliery, the distance above the Chemiss seam is only 120 feet.

The following is a section of the seam in the Michael pit (Fig. 16, Plate XX.):—

| | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|
| *Roof:* Blaes or shale ... ... ... ... | 4 | 6 | | |
| | | | 4 | 6 |
| *Seam: Dropping—* | | | | |
| COAL ... ... ... ... | 0 | 8 | | |
| Splint COAL ... ... ... | 1 | 0 | | |
| | | | 1 | 8 |
| *First working—* | | | | |
| COAL ... ... ... ... | 4 | 3 | | |
| Soft fire-clay, holing ... ... | 0 | 6 | | |
| Wild parrot COAL ... ... | 0 | 9 | | |
| | | | 5 | 6 |
| *Thill:* Soft fire-clay ... ... ... ... | — | | — | |

This coal does not vary much in total thickness, but it is a little differently made up in Leven colliery. There the top portion of the seam is a hard splint 14 to 18 inches thick, left as roof, as it is rather coarse. Below that is good coal, 3 feet thick, then after a parting of fire-clay, comes the bottom coal about 1 foot 10 inches thick, and below this is a fire-clay pavement.

The same section holds good at Durie colliery, but the holing is made in about 1½ feet of fire-clay lying below the coal; while in Leven colliery, the holing is usually made in the coal lying above the parting, owing to the bottom fire-clay being too hard. In Leven, about 3½ feet of the blaes roof is taken down in the roads, and built along the roadsides, and some of it in the faces. In the blaes, above mentioned, there is what is popularly called a "mussel-bed." It is a band composed almost entirely of *Anthracosiæ* and is about 6 inches thick. Besides this, the shells are scattered pretty plentifully throughout the blaes-roof for a thickness of a few feet.

The Barncraig or Eight-feet coal is a very bright, free coal, and is sold for household coal as well as for steam purposes. The only drawback is the cost for repairs in the pit, the roof and pavement are both rather tender as a rule, and the roads are difficult to keep, more especially in places which are damp.

The seam is worked in the Durie, Leven, Denbeath, Muir-edge, Rosie and Michael pits.

*Wall Coal.*—About 45 feet above the Eight-feet (in Leven colliery) is the Wall coal. This seam varies from 2 feet 4 inches to 2 feet 8 inches in thickness, it has only recently been opened out, and it is not certain whether it will be a paying subject.

The roof is of dark blaes with ribs of ironstone, and is fairly tough. The pavement is fire-clay, and the holing is made at present in 9 to 18 inches of it. The coal itself is very good, and leaves a brown ash. It is a bright coal, somewhat tough, and will probably make a good second-class house coal. It is being worked at no other colliery as yet. In the Michael pit, at Wemyss, it appears to be only 1 foot thick, and at Muiredge colliery only 1½ feet thick.

*Pilkembare* Seam.—The topmost coal of all (excepting a few beds less than 1 foot thick) is the Pilkembare seam. It is 3 feet 9 inches thick at Wemyss, and is of the same thickness at Leven, but it is being worked nowhere as yet. It is not of such good quality as the Wall coal.

*Marine Bed.*—This bed was first noticed in 1885 by the late Mr. J. W. Kirkby, at Denbeath pit, then being sunk, and he discovered marine shells in a black parrot-like shale, which had been thrown out on the spoil-heap. This band was found to lie about 210 feet above the Eight-feet coal. The prevailing shell is *Lingula mytiloides*, but some other mollusca are also present.*

The bed was afterwards found on the sea-shore to the east of West Wemyss, and it would appear to lie about 300 feet above the Eight-feet coal in the Michael pit. It was not found in the Durie sinking, although a look out was kept for it.

*Ochres.*—In the Leven and Durie portions of the coal-field several seams of yellow ochre occur in the Red Beds, above the workable coal-seams. Although not now worked, they were, at one time, rather extensively mined. Some of these beds are comparatively pure, and others are mixed with beds of blaes or shale.

About 60 years ago, ochre was worked from a pit near the side of the road down to Methil, and about ½ mile to the west of

* "The Occurrence of Marine Fossils in the Coal-measures of Fife," by Mr. J. W. Kirkby, *Quarterly Journal of the Geological Society of London*, 1888, vol. xliv., page 747.

where Leven Nos. 1 and 2 pits are sunk. The good ochre was picked out from the blaes, etc., on the pit-head, and was carted to West Wemyss, where it was crushed in pan-mills and mixed with water. The liquid was then run into shallow troughs, heated from below. When the ochre was dried in this way, it was again ground down to a fine powder and packed into casks for shipment. The selling price was about £15 per ton.

Ochre was also worked on the Durie field about the same date, or a little later.

It is rather strange that the ochres, which are so extensively developed in the eastern end of the coal-field, are not seen at Wemyss. The same beds are very probably present, but they must have lost their colouring-matter.

On analysing the section of the metals in the Upper or Red beds it is found that there is about 50 per cent. of sandstones. The other half is made up of fire-clays, shales and marls. In the Lower beds, containing the coals, there is only about 10 per cent. of sandstones.

One or two of the sandstone-beds may be traced through the field almost as easily as the coal-seams. A bed is seen in the section of the Michael pit, lying about 36 feet above the Pilkembare coal, 85 feet thick. In Leven pits, it is 48 feet above the same seam or 114 feet above the Eight-feet seam, and 82 feet thick. In Durie colliery, it is only 66 feet thick, and is about 120 feet above the Eight-feet seam.

The diminution in thickness of the strata between the coal-seams, and also in the thickness of some of the seams themselves has already been alluded to, and the cross-section (Fig. 11, Plate XX.) of the field from the Michael pit to Durie, and the vertical sections (Fig. 3, Plate XIX.), have been prepared to shew the same.

Although the general dip of the strata is towards the south-east, it will be seen from the map that there is an exception not previously mentioned, as the seams to the east of Durie shafts rise instead of dipping to the south-east. The seams in that portion of the Durie colliery are much troubled, and too thin to be worked. It would appear that the fault on the north and the one on the south of the Durie coal-field, run together, at no very great distance away, and this may account for the troubled nature of the seams.

## Water.

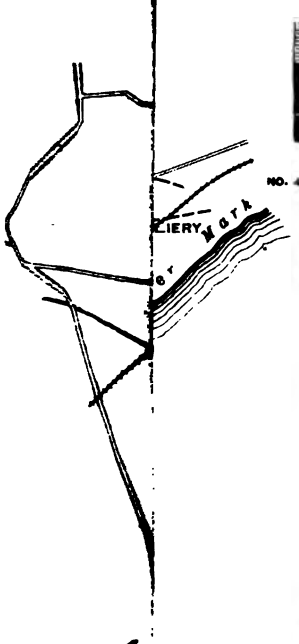
The Dysart to Durie coal-field has a fairly large amount water in it, and approximately 7,000 gallons per minute pumped from 14 shafts. Durie colliery was formerly the wett and as much as 1,600 gallons per minute was pumped at one ti during the sinking. The growth is now about 900 gallons minute. One of the feeders was very salt, containing about grains in a gallon.

In conclusion, the writer may say that there are two interesti problems to solve in this field in the near future: (1) The ext and quality of the undersea coal; and (2) the depth to, and thi ness of, the coal-seams in the Limestone-measures.

The writer is much indebted to Mr. John Gemmell, of Ed burgh, to Mr. James Hardie, of Wemyss, and to Mr. A. G. Patt son, of Dysart, for information used in the writing of this paper

### Appendix I.—Depth of Shafts, etc.

| Names of Collieries and Pits. | Names of Seams. | Depths to Seat Feet. |
|---|---|---|
| Balgonie, Julian Pit ... ... | Dysart Main ... | 498 |
| Cameron, Isabella Pit ... ... | Do. ... | 438 |
| Denbeath ... ... ... | Eight-feet ... | 690 |
| Do. ... ... ... ... | Chemiss ... | 906 |
| Durie ... ... ... ... | Eight-feet ... | 472 |
| Do. ... ... .. ... | Six-feet ... | 510 |
| Do. ... ... ... ... | Chemiss ... | 594 |
| Dysart, Frances Pit ... ... | Dysart Main ... | 594 |
| Do. do. ... ... | Seven-feet ... | 672 |
| Do. Randolph Pit ... | Dysart Main ... | 600 |
| Leven, Nos. 1 and 2 Pits ... | Eight-feet ... | 723 |
| Do. do. ... | Six-feet ... | 762 |
| Do. do. ... | Chemiss ... | 870 |
| Do. No. 4 Pit ... ... | Eight-feet ... | 330 |
| Do. do. ... ... | Six-feet ... | 378 |
| Muiredge . ... ... | Chemiss ... | 474 |
| Do. ... ... .. ... | Parrot ... | 828 |
| Pirnie ... ... ... ... | Do. ... | 348 |
| Rosie Pit ... ... ... | Eight-feet ... | 378 |
| Do. ... ... ... ... | Chemiss ... | 592 |
| Wellsgreen ... .. ... | Dysart Main ... | 504 |
| Wemyss, Lady Lilian Pit ... | Do. ... | 378 |
| Do. Michael Pit ... ... | Barncraig ... | 540 |
| Do. do. ... ... | Chemiss ... | 798 |
| Do. Victoria Pit ... ... | Bowhouse ... | 309 |
| Do. do. ... ... | Coal More ... | 450 |



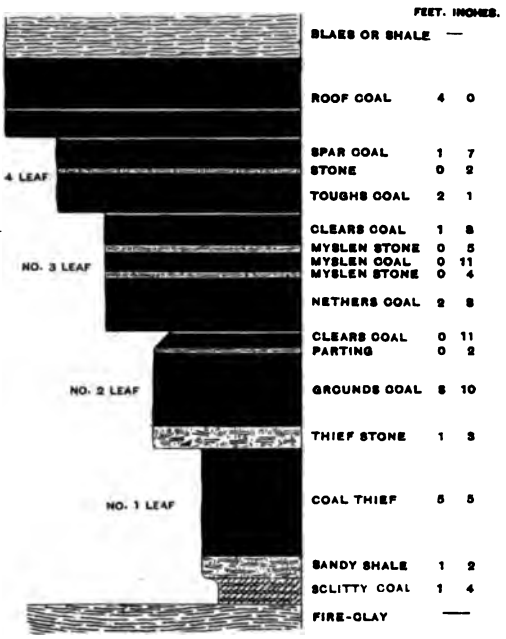
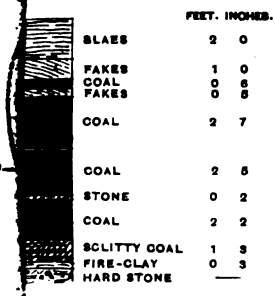




FIG. 4.—DYSART MAIN SEAM, VICTORIA PIT. WEMYSS COLLIERY.

*Scale, 10 Feet to 1 Inch.*




VHOUSE SEAM. LADY PIT. YSS COLLIERY.

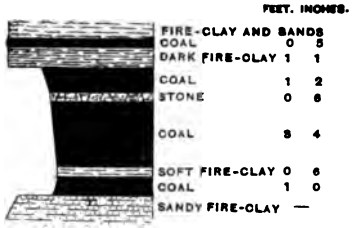
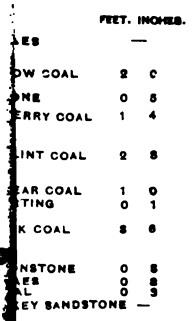



FIG. 6.—WOOD SEAM, WELLSGREEN COLLIERY.




KIRKCALD

MICHAEL PIT.

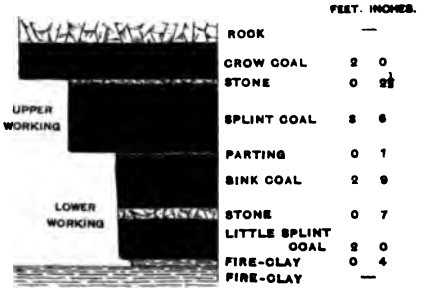
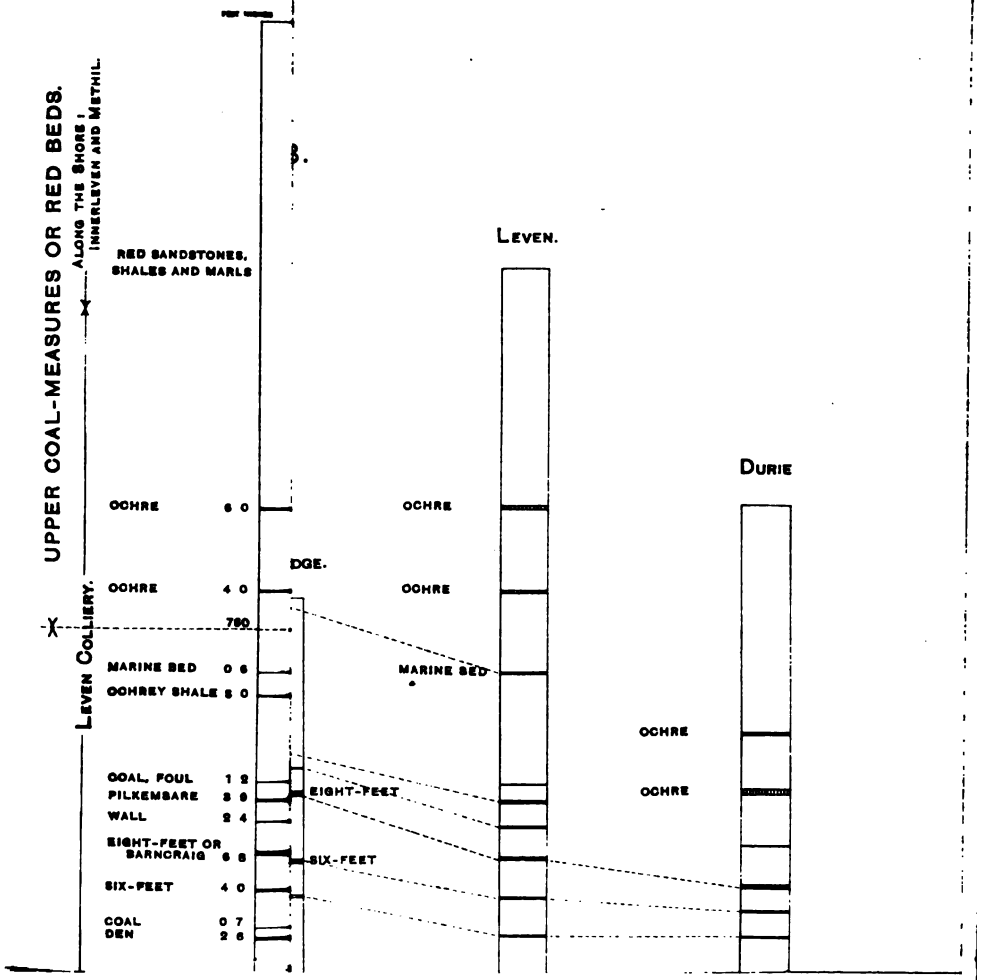



FIG. 8.—CHEMISS SEAM, LEVEN COLLIERY.

*Scale, 10 Feet to 1 Inch.*

*and Leven Coal-field, Fifeshire.*

FIG. 2.—GENE



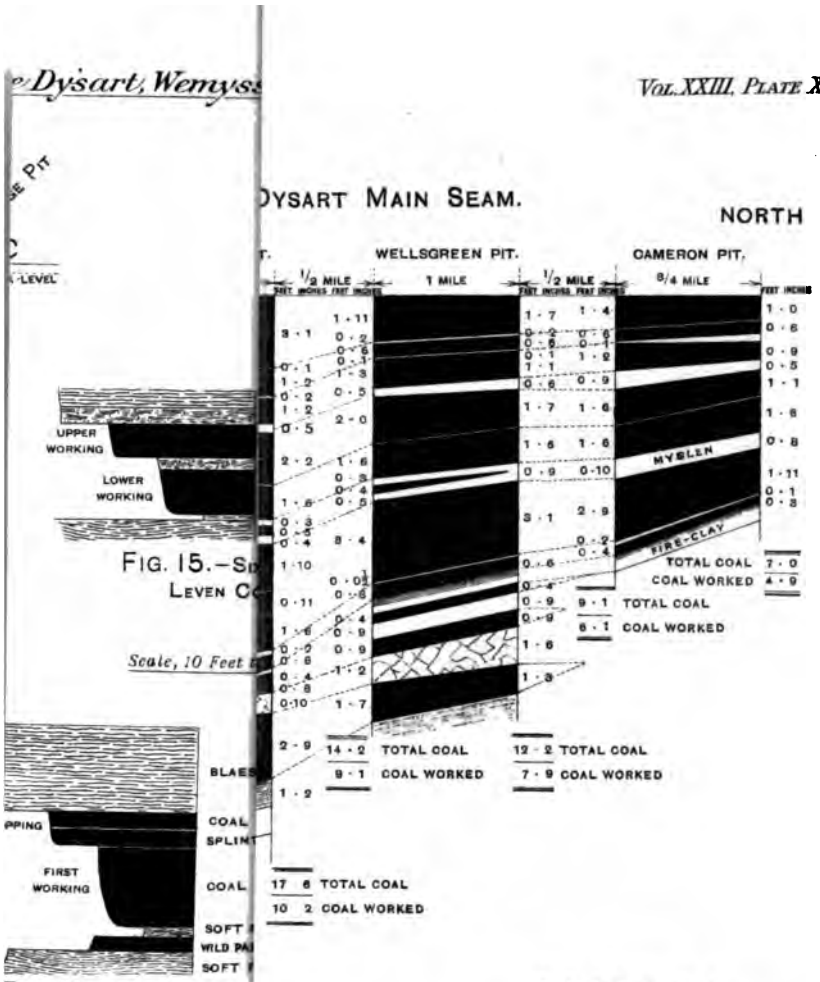
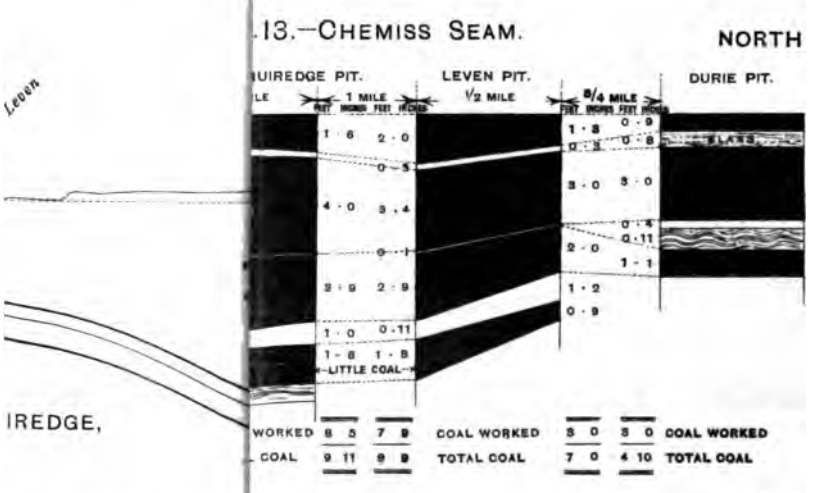



FIG. 15.—SE
LEVEN CO

FIG. 16. BARNCRAIG SEAM
WEMYSS COLLIE




Rend & Comp.y L.td Newcastle on Tyne.

The PRESIDENT (Mr. Henry Aitken) said that Mr. Kirkby had submitted a very interesting and detailed account of a portion of the coal-field of Fife. Not being familiar with this part of the Fife coal-field he would leave the discussion of the general features of the field to others; but there was one point, which was worthy of notice from a geological point of view, and it was as follows, namely: "This bed was first noticed in 1885 by the late Mr. J. W. Kirkby, at Denbeath pit, then being sunk, and he discovered marine shells in a black parrot-like shale, which had been thrown out on the spoil-heap."* Doubtless, these shells were of the same type as those found in the same section of the coal-field in the west of Scotland, and of which several beds exist; and these shells are also of much the same types as those found in the sea, but were they sea-shells? He thought not, as coal must have grown by fresh-water or in it. How could salt and fresh water have been turned on and off to produce the alternating strata, which are now seen? He was of opinion that these are fresh-water shells, and not salt-water shells. In the Coal-measures, and indeed in all the strata up to comparatively recent formations, the absence of any great amount of salt is most marked. In Lake Tanganyika (a fresh-water lake in Central Africa), what are called marine fishes and shells are found, and specimens can be seen in the British Museum.

Mr. R. T. MOORE (Glasgow) said it was very interesting to have the fullest information with regard to this coal-field. He did not know whether Mr. Kirkby had looked into the matter, but the connection between the various coal-fields was worth studying. The general idea was that the Chemiss seam corresponded with the Jewel seam in Midlothian, the Splint seam in Lanarkshire, and the Ayr Hard seam in Ayrshire; and that the Dysart seams corresponded with the seams about the Kiltongue seam and those underlying it in the Shotts district. In Midlothian, the Cowpits seams which corresponded with these seams had been opened out, and there were several thick seams of coal. Mr. Kirkby had pointed out that the thickness of the Coal-measures was some 2,400 feet, but it would also be interesting to know the distance between them and the coal-seams in the Carboniferous Limestone series.

So far as he was aware, the only place in Scotland where Carboniferous Limestone coals had actually been worked below the

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 306.

upper seams was in the Edinburgh coal-field. At Niddrie, the highest of these coals—the Great seam—which correspond with the Cairncubbie seam of the Fife district, had been worked at a depth of 2,700 feet below the outcrop of the Jewel seam, which (as he had said) was the equivalent of the Splint seam of Lanarkshire, and at this point the lower seams were of value. Now that the coal-resources of the country were being considered, it was important to try to form an opinion as to the value of the unproved coal-fields, and in Scotland there were the several areas of the Upper Coal-measures under which there was a possibility of finding large quantities of coal in the Carboniferous Limestone series.

With regard to the Dysart coal-field, they knew that on the western outcrop, towards Thornton, the lower seams were thin as they approached the Upper Coal-measures. On the other hand, on the eastern outcrop, at Pittenweem, there was a considerable number of thick workable seams; and on the southern outcrop in the Lothians, the Carboniferous Limestone seams were also found in good workable condition. On the whole, the probabilities seemed to be in favour of the lower seams being found in good workable condition in at least a considerable area of the Dysart coal-field and extending under the Firth of Forth. They would no doubt occur at a great depth, but not beyond the limits of possible working.

# MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE ARCADE HALL, BARNSLEY, MARCH 8TH, 1902.

MR. JOHN GERRARD, PRESIDENT, IN THE CHAIR.

The minutes of the previous General Meeting were read and confirmed.

The following gentlemen were elected, having been previously nominated:—

MEMBERS—

Mr. WILLIAM HALDANE GALLETLY, Mining Engineer, Parkhill Colliery, near Wakefield.

Mr. CHARLES LEA, Manager, Ffrwd Collieries, Ffrwd, Wrexham.

Mr. JOHN PAXTON, Mining Engineer, 26, Petersen Road, Wakefield.

Mr. RICHARD PURDY, Colliery-manager, Topcliffe House, Tingley, Wakefield.

ASSOCIATE MEMBER—

Mr. EDWARD GREAVES, Sharrow View, Sheffield.

ASSOCIATE—

Mr. ARTHUR WILSON, Colliery-manager, South Field Farm, Norristhorpe, Liversedge, Yorkshire.

Mr. W. E. GARFORTH read the following paper on "The Application of Coal-cutting Machines to Deep Mining":—

# THE APPLICATION OF COAL-CUTTING MACHINES TO DEEP MINING.

By W. E. GARFORTH, M.Inst.C.E., F.G.S.

## Introduction.

Considering the growth of international competition, keener at the present time than ever contemplated, even a few years ago, and taking into account the enormous interests involved in the coal-trade of this country, the writer feels that no excuses need be made to the members of this Institute for the introduction of a paper dealing with the winning of coal.

Complaints have been made respecting the needless waste underground in the process of getting coal, and suggesting further need for greater economy in its consumption. These complaints can as justly be made to-day as in 1866, when a Royal Commission was appointed to consider "the probable duration of the coal-fields of the United Kingdom." At that time, 1866, the annual production of coal was 101,630,544 tons; the last return, 1901, shews the output to be 219,037,240 tons; or, an increase during the past thirty-five years of 115 per cent.

It is satisfactory to know that the mining-engineer, and the colliery-officials and workmen associated with him, have been able not only to extract this large tonnage of coal from a greater average depth than formerly, but in the hazardous operations which this involves there has been a great decrease in the number of lives lost. For the five years previous to the publication of the *Report*, 93,866 tons of coal were raised per annum per life lost, as compared with 201,501 tons per annum during 1894-1899, or a saving of life equal to 114 per cent.

With regard to the opinions expressed on the finding of the *Report* and the difficulties experienced by the Commissioners appointed to acquire evidence, who had the advantage of having placed before them the opinions of the best scientific and most experienced specialists, it would appear mere guess-work, without

obtaining a continuation of such evidence, which is not at present available, to formulate a trustworthy opinion on the subject of "the probable duration of the British coal-fields."*

But beyond the discussion of such duration, there is the vital question as to whether coal can in future be raised and sold at such a price as will enable British manufacturers to compete successfully with those of other countries. The rapid exhaustion of the thicker seams at shallow depths; the necessity for working the thinner seams, and enquiries if such seams are unduly injured by the present methods of working the thicker and under-

FIG. 1.—BORD-FACE IN THE STANLEY MAIN SEAM, 6 FEET THICK AND 240 FEET DEEP: THE COAL IS INTERSTRATIFIED WITH DIRT-PARTINGS FROM 4 TO 6 INCHES THICK.

lying seams; the tonnage lost in working; the increased percentage of small coal; the loss by barriers left for boundaries, and by pillars required for the support of surface-property; the difficulties due to scarcity of labour, especially hewers; higher wages; and other matters, have already caused anxiety as to the future prosperity of the coal and other trades of this country. Hence,

* Since this portion of the paper was written, a Royal Commission has been appointed to consider amongst other matters the points above referred to.

all methods of getting or dealing with coal which seek to meet these difficulties, or by which the "greatest proportion of workable coal can be raised in the best condition, at the lowest cost of production, and with the greatest safety and comfort to those employed" are subjects that should be fully and often discussed by those interested in mining.

Though statistics and the past history of mining may prove that great progress has been made generally, yet improvements in the actual process of winning the coal are few, as these are dependent on certain natural conditions, in overcoming which, considerable difficulties are experienced. Many of the conditions suitable to mines lying less than 1,000 feet below the surface, are not applicable to seams at a depth of 2,000 feet. Deep mining has already demanded, and must still further demand the discarding of many of the past usages of working coal. Parliamentary legislation has also, within recent years, imposed restrictions which have placed mining on a higher and safer level than formerly, and, mining practices, which a few years ago were considered as well within the limits of safety, are now condemned as unsafe and are legally penalized.

The writer hopes to prove that the natural difficulties experienced in maintaining underground roadways, due to the increased thickness of the overlying strata, may be lessened; that the percentage of crushed coal may be reduced; and that mines formerly looked upon as unprofitable may be worked with advantage.

To obtain these desirable results, certain fundamental laws of Nature, which are in full evidence underground, must be more closely recognized and carefully followed; and while the damaging effect of the superincumbent weight must on the one hand be guarded against, on the other it should, to a greater extent than hitherto, be utilized, by transforming it into a power to replace the use of explosives. By the miner, a weight thus utilized may be looked upon as Nature's lever, somewhat as the farmer looks upon ice as Nature's plough. From lack of knowledge, or non-recognition, full advantage has not been taken of those natural laws which thus lie within man's reach, and by which in future he may be more directly benefited. Previous discoveries shew that "Nature does not volunteer information which man may discover for himself, probably for the reason that when

man is capable of appreciating it, he is capable of discovering it." History shews that originally mining was conducted on non-scientific lines, and many of its practices were and are still empirical, and the result of its present efficiency, which has required a century for its development, has been obtained at a great sacrifice of human life.

It is not intended in this paper to refer to the serious difficulties connected with increased temperature, one of the two most serious obstacles to deep mining; nor to the various details connected with hauling, screening, washing or otherwise dealing with the coal

FIG. 2.—CLEATAGE-PLANES IN COAL AND ROOF OF THE SILKSTONE SEAM, 4 FEET THICK AND 960 FEET DEEP.

underground and on the surface, as these subjects have for several years past afforded matter for interesting discussions at the meetings of mining institutes.

## COAL-SEAMS.

It is rather with the coal-face that the writer wishes to deal, as it is thought, after making full allowance for the improvements which have been made in the working of mines during the past 30 years, that further improvements may be introduced by

retaining the best of all that is good in the older methods; and supplementing them by later mining practices based upon scientific principles.

Before, however, describing certain details connected with the practical working of the coal-face, it is considered necessary to direct attention to some of the physical properties of the coal, roof and floor, and the effects produced upon the seam by pressure due to superincumbent weight and lateral expansion induced during the process of extraction.

In describing the actual appearance of the coal-seam and by introducing photographs* of its environment, it is hoped that some of the points raised may form the subject-matter for further discussions by the members, and that the investigations of the geologist and physicist, which bear on mining, may in the future be more fully utilized for the practical benefit of the miner, who, though he is well acquainted with the effects produced underground in mining coal, requires fuller information on the exact causes which govern them.

Briefly it may be said, that a piece of coal reveals by its shape the influence of certain Divine laws, which appear more marvellous the better they are understood. The dull, sooty divisions of the coal-seam indicate lines of deposition: the bright continuous cleatings which constitute the face or bord of the coal, are the impress of great earth-movements: while the jointings running at varying angles to the cleatage-planes, shew the effect of shrinkages of the strata. In addition to these three natural divisions, artificial lines of fracture may be induced which further alter the shape of the coal.

Considered more fully, coal-seams appear to rest in horizontal or inclined positions when viewed in short sections, but broadly they are curved and form parts of great rock-foldings. The dirt-partings, between the upper and lower surfaces of the seams, formed of sifted mud precipitated in water, mark the original lines and direction of the deposition of the coal, whilst underlying the seam is the seat-earth, above which was once uplifted the growth of vegetation which afterwards fell, and eventually became coal, to be again covered and separated by silted

* Some of the photographs attached to this paper were taken about 3½ years ago with an incandescent light of 450 candlepower, and in some instances nearly 1 mile from the shaft.

material (Fig. 1). Some of these smooth surfaces which possess fine continuous lines of lamination facilitate the winning of the coal, as they induce a weak adhesion to the roof, whilst in others the rough or uneven surface causes a binding or sticking of the coal to the roof.

The cleatage-planes forming the right and left faces of the coal (especially noticeable in binds and shales and in some coal-fields more than in others) run parallel with the flexures or folds of the hills, approximately from north-north-east to south-south-

FIG. 3.—MAJOR JOINT IN BORD-FACE OF THE SILKSTONE SEAM, 4 FEET THICK AND 960 FEET DEEP.

west and at right angles to the direction of those great earth-thrusts by which the hills were uplifted. Within the earth, as proved by various strata exposed on the surface, or met with in sinking pits, these lines run through rock-masses of great thickness and varying compositions, usually nearer together in finer grained rocks, and wider apart in those of coarser structure (Fig. 2).

It may be generally stated that cleatage, like cleavage, of which it seems to be a form, may be accompanied by shear, or a

sliding of one set of rock-particles over another set, the faces of which may move at different velocities, or one may be at rest; and the polish or brightness of the divisional planes of the coal points to such a molecular movement, or rearrangement of the coal-particles by mechanical stress. As a consequence, the cleatage-planes of coal differ in appearance, though not in composition, from the mother or parent-rock of which they are a part.

The natural divisions forming the hackly front and back faces of the coal vary in appearance, but usually consist of high-angled joints, due principally to shrinkages of the strata, by evaporation of water and escape of gases accompanied by minor thrusts during the process of drying and consolidation. Such joints often run at high angles to the bedding, or at various angles, sometimes approaching right angles, to the cleatage-planes to which they seem at times to be similar in character though they are never associated with shear (Fig. 3).

The faults met with in the Coal-measures are due chiefly to uneven settlements of the strata and other influences, and a mere enumeration of these, and how their occurrence has often led to the disorganization of all systems of working, would exceed the limits of this paper.

In addition to the natural divisions referred to, there are induced fractures, such as are set up in the working of the coal, which also contribute in the defining of its size and shape (Fig. 4). Such fractures arise when the coal is mechanically assisted or induced to part from the roof by excavating the lower portion of the seam to such a depth, that the remaining overhanging portion falls by its own weight, or when assisted by the action of explosives.

From these facts and others, indicated in the illustrations, it will be seen that the straight lines of cleatage are visible indications of natural laws, which have in the past been well known to the miner, and served as a guide in driving narrow and straight roadways or in maintaining a longwall face at any required angle to the cleatage-planes or bord-face.

### Longwall-working.

When the seam is first cut there is a lateral expansion of the coal, especially in seams where the portion exposed is parallel to the planes of cleatage. While the coal-seam remains untouched,

no movement, unless it be an earth-movement, can take place even in deep seams where the weight of the overlying strata nearly approaches the cohesive strength of the coal. But, immediately an excavation is made, a movement results, approximately proportionate to the cohesive resistance of the coal and the pressure of the overlying strata.* If the floor or dirt-parting in the seam is softer than the coal, the crushing effect on the latter is diminished; and as recently proved by making an excavation in the

FIG. 4.—LINES OF INDUCED FRACTURE AND CLEATAGE-PLANES IN ROOF OF THE SILKSTONE SEAM, 4 FEET THICK AND 960 FEET DEEP.

upper portion of a seam between 2,000 and 2,500 feet deep, an effect is produced from below which assists to win the coal as if the thrust were in a vertical direction.

After an excavation has been made in or under the seam to induce the upper part of the seam to fall, the roof or overlying stratum is thrown upon the remaining portion of the coal-face. As the width of the excavation increases, the immediately overlying stratum settles down on the coal-face and pack, and a species

* The writer intends, on some future occasion, to introduce the results of certain experiments and observations which have been made under his direction, to show the extent of lateral expansion in narrow roadways and on longwall-faces within given periods of time.

of "arching-over" takes place in the overlying stratum, something like a girder, supported respectively by the coal-face and dirt-pack. As the span increases, additional weight is thrown upon the coal-face and pack-walls, with the result that the former is crushed, which is detrimental, and the latter consolidated, which is desirable for many reasons connected with safety as well as profit. The longer the time to which the face is subjected to such weight, especially if its line be irregular, with projecting pieces of coal, the greater will be the production of low-priced coal; and the quicker a straight fracture is induced, by which the maximum superincumbent weight is thrown on the pack, the larger will be the yield of high-priced coal. If, in addition to such a face-break, other fractures and settlements can be frequently induced, the coal is not only relieved, but the strata immediately above the pack and extending for some distance into the goaf become disintegrated, with a greater tendency to settle down quickly and vertically upon the pack-walls, than where the cohesive strength of the overlying strata is maintained and the weight is thrown forward on the coal-face.

From the foregoing, it will be apparent that the crushing-effect on the coal may be minimized by pushing forward the whole length of the coal-face, and by having the least length to maintain under its influence compatible with the required output. This arrangement can, unless exceptional natural difficulties intervene, be carried out most effectively by having a straight line of face, produced by a straight line of cut, inducing a straight line of fracture in the roof, which is supported by a straight line of timber (Figs. 18, 19 and 20, Plate XXI.). This method of working permits of, or leads to, a more systematic use of timber than where the breaks are irregular and the timber is set following these irregularities. In addition to these advantages, there are fewer roads to maintain and less timber, rails, etc. are required (Fig. 21, Plate XXI.). While formerly it was physically impossible to obtain by handworked picks such a rapid advance of face as is now advocated, yet such an advance may be obtained, at the present time, by mechanical appliances actuated by compressed air or electricity.

For some years past, certain coal-faces cut in a perfectly straight line have been advanced at the rate of 16½ feet per week; and experience has shewn that, with certain exceptions due to

natural conditions, there is nothing to prevent a greater advance by specially arranging for continuous shifts, so that the coal may be filled immediately after the cut is made (Figs. 21, 25, 26 and 27, Plate XXI.). The advance of face requires to be regular both as regards cutting and filling, as opposed to quick filling and leaving the next cut for too long a period, which allows the coal to be crushed and is attended by other disadvantages.

From a careful study of the natural phenomena indicated by the foregoing, and a personal experience gained in working coal-seams from a depth of 240 feet (where pillars of coal left 30 years

FIG. 5.—HOLING IN COAL BY HAND, WHEN THE THILL IS TOO HARD FOR PICK-WORK, IN SILKSTONE SEAM. STRONG SPRAGS AND COCKER-POLES ARE USED TO SUPPORT THE COAL, AND MAY BE COMPARED WITH THE WEDGES USED IN MACHINE-WORK AS SHEWN IN FIG. 11.

ago are still standing as efficient supports to the main roadways), down to a depth of 3,300 feet below the surface, where portions of the coal become crushed to small pieces after a few hours' exposure, the writer is convinced that if deep coal-seams are to be successfully won, a practical acquaintance with certain natural laws and their effects will in future be essential to colliery-officials and workmen. Speaking generally, it will be found that in deep, equally with shallow mines, there is a much greater uniformity of

conditions than is supposed, and that while coal-seams vary, in depth, thickness, inclination, etc., still the general and main principles connected with their deposition, cleavage, jointings, and lateral expansion, apply almost equally to all seams; and, with certain exceptions, allow the same general method of working to be successfully carried out in deep seams.

When there appears to be a difference between Nature and science, it will be proved, in mining as in other past instances, that the fault does not rest with Nature and that certain laws now imperfectly understood will in the future be more fully appreciated. As an instance of this, imagine the difficulties and increased cost that would attend the working of coal, rocks, and other minerals, if the same were one homogeneous mass instead of being divided by the divisions due to deposition, cleatage and jointings.

The earliest system of working coal was to drive a narrow road in the seam and to leave large supporting pillars—a method probably or partly based on self-preservation. An extended knowledge of the nature of the coal, and the methods of maintaining the roof, led to the roadways or stalls being increased in width and the pillars proportionately reduced. This method of working called "pillar-and-stall" or "stoop-and-room" was attended with success, and became perfected by many years of practical experience, with modifications, to meet different local conditions. When the depths of seams from the surface increased, it was recognized that the size of pillars, which were left in the first process of working, should be enlarged, to withstand the greater superincumbent weight.

Before the effect of the weight was generally realized by the past generation of colliery-officials, serious trouble and loss were experienced in working mines exceeding a depth of 600 or 700 feet. And by leaving an increased size of pillar, the pillar-and-stall system has been carried on in some mines for a longer period than is consistent with profitable working.

Experience has proved that no system of working can reduce the pressure on the coal remaining to be worked, and this fact becomes more and more apparent as the depth of the coal-seam below the surface increases. Each square foot of coal supports a corresponding area of roof, but when a portion of the coal is removed in the process of mining, then an enhanced weight, over and above what may be termed the natural weight, is thrown upon

the remaining portion. For many years, it has been recognized that such complaints as tender coal, bad roof, lifting floor and sudden outbursts of gas were often due to faults of the pillar-system, and not, as formerly alleged, to the inherent weakness of the coal and adjoining strata. It is generally admitted, even by the present advocates of the longwall method, that, within a certain depth, no system has been attended with greater success than the pillar-and-stall method as practised and perfected in the North of England, Scotland, and other mining districts. Eventually the system of leaving pillars or working the mine by

FIG. 6.—HOLING IN THILL, BY HAND, IN SILKSTONE SEAM.

two operations was abandoned in deep mines, in favour of longwall or of extracting the seam at one operation.

Formerly it was considered that this latter method could only be carried out when the roof and pavement were good, inclination suitable, etc., yet excessive superincumbent pressure resulting in an excess of small or low-priced coal has compelled its adoption under almost all conditions met with in deep mining. This loss consequent on having to sell a portion of the small or crushed coal at a price so much below the cost of production would have been more severely felt in past years had it not been for the large quan-

tity of the same class of coal required in the manufacture of coke and the mechanical appliances which have been invented to utilize it for raising steam and certain manufacturing purposes. The advantages claimed for the longwall method are too well known to need recapitulation, but amongst others the writer gave the following opinion in May, 1882:—"The straight line of face affords the best lines of fracture, and by allowing the subsidence of the superincumbent weight to be regular and to fall on the goaf, thus taking the pressure from the coal-face, stalls are seldom stopped by weighting-in, and there is less liability to sudden outbursts, as the pent-up gas may be liberated in small quantities and regularly dealt with."*

The experience of the past 20 years, but especially of the past 10 years, has, however, shewn that in longwall working by hand-holing, there are serious disadvantages, including amongst others:—(1) Under-cutting the back of the holing in an irregular line; and, when an extra depth of holing is necessary to ensure the excavated coal breaking from the solid portion, cutting or slabbing part of the solid face into small pieces to permit of shoulder-room for the workman (Fig. 5). The projections at the back of the holing act as struts almost as effectively as the sprags in front of the coal-face, especially when assisted by the undermined coal adhering to the roof and the back of the solid coal. The projecting portions are consequently exposed to an excess of crushing-weight, which is further increased by the cut at the back of the excavation being of so small a height that when the overlying weight comes into operation, there is not sufficient space in the holing to avert its immediate effect, and the coal (being usually softer than the roof and floor) suffers by such association. (2) Under-mining one part of the coal-face at a period of time different from the adjoining portion, consequently additional weight is thrown on the remaining portion of the holing-dirt; and this is, therefore, crushed and more easily worked—an advantage to the miner, but gained at the expense of the coal-owner, as a greater percentage of low-priced coal is produced. (3) In order to maintain a large and regular output, an increased length of face is opened out, which becomes subject to the crushing effect of the overlying weight, especially in summer or when trade is bad and short time is worked. It may be pointed out that a coal-face,

* *Trans. Midland Inst.*, 1882, vol. viii., pages 36 and 37.

1,100 feet in length multiplied by 16½ feet of advance or width per week cut by machines, produces the same quantity or area of coal as a coal-face 3,000 feet long advancing 6 feet per week—the latter being the ordinary advance by hand-holing (Fig. 21, Plate XXI.). By this method of a quick advance, 1,900 feet of coal-face is saved from the crushing effect of the overlying strata with the additional advantages of fewer roadways to maintain, less materials required, etc. Figs. 22, 23 and 24 (Plate XXI.), taken from actual measurements in the mine, show that the pick-line.

FIG. 7.—COAL-CUTTING MACHINE, PLACED ON CROSS-RAILS AT AN ANGLE TO THE WORKING-FACE, COMMENCING TO CUT INTO THE COAL.

as left by the miner, is a sinuous or crooked one, due to the difference in skill and attendance at work of the men engaged in the working-places. When the dirt below the coal admits of a greater thickness of excavation (Fig. 6), these effects are minimized, but not to the same extent as if the cut were perfectly straight and quickly produced, which is impossible to obtain from a workman lying in a cramped position, and swinging a pick at a distance of some feet away from him in the attempt to produce a straight line of holing.

If the coal-face be worked on a curved line, the difficulties previously enumerated are intensified by reason of the projecting angles which cause irregular lines of fracture and prevent a regular settlement of the strata. If it be correct to work coal by following straight lines, either on the principle of (*a*) plumb-end, (*b*) bord, or (*c*) half end and half bord, then the coal-face cannot for the reasons given be advantageously worked at constantly varying curves and angles. When the coal is worked end on, it may be said to have its maximum strength to resist pressure, and

FIG. 8.—COAL-CUTTING MACHINE, AT A REDUCED ANGLE TO THE WORKING-FACE, OWING TO THE WHEEL HAVING CUT 1 FOOT INTO THE COAL.

allows the deepest excavation to be made before the coal falls, usually in large pieces and with a cubical fracture, even in the smaller pieces. On the other hand, the coal most readily falls when worked bord-way, or when the lines of cleatage run parallel with the cutting, in which case friable, slabby, and an increased percentage of fine-coal results. A modification of the above system is the working of the seam by end and bord. As the line of break follows the line of the least resistance so the straight line of coal-face may be worked at any angle, as experience gained in working particular seams may require.

Judging by the losses already suffered by the production of small coal, it is natural to expect within the next few years, as deeper seams are worked, that the ill effects of superincumbent weight on a crooked longwall face, will be as well recognized as those which led to the abandonment of the pillar-system.

The writer wishes it to be understood that the suggestions and opinions herein expressed, relate to the general methods of working coal in flat or slightly inclined seams, and that there are exceptions to every rule. For instance, the steepness of a mine,

FIG. 9.—COAL-CUTTING MACHINE NEARLY PARALLEL TO THE WORKING-FACE OWING TO THE WHEEL HAVING CUT 4 FEET INTO THE COAL.

where the end or bord of the coal runs at almost right angles with the line of level, may cause difficulties in the conveyance of coal, or the influence of faults or other local circumstances may counterbalance the advantages referred to, by preventing the general principles herein suggested from being carried out. At the same time, important advantages are being obtained in certain German mines, where the writer recommended the use of coal-cutting machines in coal-seams lying at an inclination of 30 degrees.

## Mining with Coal-cutting Machines.

As the longwall system seeks to minimize the crushing effect of the superincumbent weight on the coal, and to replace the pillar-and-stall system, so must the pick as a holing tool give way to the coal-cutting machine, with its line of cutting as straight as the rails on which it runs or the cleatage-lines which it professes to imitate. This displacement of the pick for holing will be somewhat akin to those lines of improvement by which the scythe was superseded by the mowing-machine, the oar by the screw-propeller, and the needle by the sewing-machine.

Important changes and improvements have already taken place in other mining operations, for instance, the high-speed fan, in lieu of the ventilating-furnace; mechanical power for the horse: the shielded safety-lamp for the candle; and the same evolution of improvements is now needed in the method of working the coal-face.

The longwall method, which many years of experience has shewn to be the only method by which the deep mines of this country can be won, has unconsciously led up to the introduction of coal-cutting by machinery. Without a long straight coal-face, the effectiveness of coal-cutting machines is minimized to a considerable extent. The extra cost of transporting machines from one short face to another, as compared with the advantages now being gained on coal-faces of 1,000 or 2,000 feet or in one case 4,800 feet in one straight length is considerable. In the thinner seams, the machines cut backward and forward; but in thicker seams, where large outputs are required, a loss arises by waiting for the coal to be filled into tubs. The experience gained in working coal-cutters during the past ten years shews that where a coal-seam, lying at a moderate inclination, can be worked on the longwall system by hand, it can, with certain exceptions, not only be worked with equal facility by machine, but with the additional advantages herein described.

Coal-cutting machines producing shallow under-cuts have been in regular use for the past 30 or 40 years, and it is said to be 140 years since the first of these machines was invented by Mr. Michael Menzies for a Durham colliery. Their use has been successful when working on the face of the coal, or under conditions where a shallow under-cut was sufficient to cause the coal to fall, or in thin seams where the underlying dirt has been excep-

tionally strong, or to obtain the effect of the superincumbent weight after opening out from the solid pillar, or financially in prosperous times of trade, owing to scarcity of workmen. Their adoption has not been as general as expected, partly owing to prejudice on the part of certain workmen, the inability of the working parts to resist undue strains, and principally because the results were not pecuniarily beneficial. Instances can be given where fruitless attempts have been made with a machine giving a cut of 3 to 3½ feet, to produce the same effects as those obtained in the same seam, where years of experience by hand-holing had

FIG. 10.—COAL-CUTTING MACHINE, THE WHEEL HAVING CUT 5½ FEET INTO THE COAL, READY TO CUT FORWARD ALONG A WORKING-FACE, 1,920 FEET LONG.

proved that nothing less than an under-cut of 5 to 6 feet was required to produce the largest output and best quality of coal and occasionally to avoid the use of explosives.

The depth of cut of all longwall coal-cutting machines introduced up to the year 1892 varied from 2 feet 10 inches to 3½ feet, with a thickness of kirving or under-cut of 3 inches. It was imagined that a greater depth of under-cut would lead to difficulties, from the cutting-wheel and accessories overbalancing the body of the machine, and that a machine of greater weight and

larger size beyond those in use would be too cumbersome to be handled in the mine.

In the year mentioned, owing to the writer being unable, after 12 months' negotiations with certain workmen, to agree to a price for getting a seam of coal, 4 feet thick, extending over a large area, besides being further restricted in the use of explosives, because of a serious explosion having previously occurred at the same colliery, he suggested a machine to make a deep under-cut. Previously, in 1876, the writer had been engaged in adapting a coal-cutter to a rotary engine, and in a paper read before the members in 1882, he stated, "it is possible that coal or dirt-cutting machines, very much modified from those at present in use, will prove of greater value than they have hitherto done, and the long straight face of the longwall system will offer special facilities for their successful adoption."* About the same time, 1882-1883, the writer had two Winstanley-and-Barker machines at work in the Haigh Moor coal-seam, but as the under-cut was only 2 feet 10 inches as compared with 5 to 6 feet usually holed by hand, both machines were abandoned as soon as the holing by hand became easier to work (by reason of the additional weight thrown on the advancing face), which enabled a getting-price for the coal to be arranged with the workmen.

The special machine referred to, with a wheel designed to under-cut 4½ feet, commenced working in 1892 under the personal direction of Mr. William Buxton, an experienced official, to whom the writer wishes to take this opportunity of expressing his best thanks for the assistance that he has rendered in the development, and especially in the application, of the deep under-cut machine. The principle of the 4½ feet under-cut with a height of 5 inches, proved satisfactory, reduced the number of shots from 37 to 17 per day, and at the same time the output per man (paid by day) was increased from 3¼ to 4½ tons per shift of 8 hours. No accidents occurred from the formation of the straight line of cut, as predicted by officials of long experience, consequently the writer pressed forward the construction of a large wheel to give 5 feet of under-cut, and on being worked, it still further increased the output per man. The men eventually accepted a price of 1s. per

* *Trans. Midland Inst.*, 1882, vol. viii., page 29.

ton instead of 2s. as originally demanded, and at this reduced price obtained a much higher wage than when working by hand-pick.

Later, the writer designed a new form of bracket for supporting the cutter-wheel, by which the depth of the under-cut was increased to 5½ feet without increasing the diameter of the wheel. This improvement gave a greater width between the roof-break and solid coal, and enabled a line of 6 inches props to be set under the solid roof, instead of near the break, an advantage which cannot be obtained when a shallow under-cut is made (Fig. 19, Plate XXI.). Still later, the use of explosives was in many

FIG. 11.—MACHINE-HOLING, 5½ INCHES THICK, TO A DEPTH OF 5½ FEET, AND STALLMAN REMOVING WEDGES.

instances dispensed with, and the output of coal increased to more than an average of 6 tons per man cut by machine, as compared with an average of 3¼ tons cut by hand.

In another seam, the under-cut was successfully increased to 7 feet (Fig. 17), but practice has shewn that this depth of straight cut is beyond ordinary requirements and may cause difficulties both from coal and roof.

The writer claims, for the preceding reasons, to be the originator of the principle of deep under-cutting by machine on the long-

wall method, and acknowledges the help received from others in carrying out details of construction, derived from actual experience at the coal-face.

Coal-cutting machines carry out in a more perfect way the principles of holing, and it will be noticed how nearly the lines of cut and artificial fracture imitate the lines of cleat (Figs. 18 and 19, Plate XXI.). It cannot, however, be expected, even with a straight under-cut, that the line of break can be as straight as a line of cleat, as the under-cut coal has to shear itself from the main block.

Science has been defined to be "the answer made by Nature to the questions put to her by man;" and in no branch of engineering is scientific reasoning more required than in coal-mining, which is largely dependent upon the effect of natural forces.

If a coal-seam be under-cut to a depth of 3 feet, and if, after the artificial supports are withdrawn, the coal does not fall: Nature shews by this answer that the breaking-depth of the seam has not been properly gauged, and the cut requires to be made deeper; or the adhesion between the roof and top of the coal, and the cohesion of the back of the excavated coal and the seam beyond, has yet to be overcome. Trial-cuts with a machine, possessing a deep under-cut wheel, must then be made until the true answer is obtained. The result of such experiments decides the depth of the under-cut, and the exact position where the incision must be made. It also indicates the form of machine, as regards height, width, and other details of construction, which must be governed by the natural conditions of the mine. To attempt to work the mine to suit a particular machine is to court disappointment and loss. Several instances could be quoted where a particular machine has given excellent results in one seam, while the same form of machine has caused inconvenience and loss in another mine, until a special machine had been constructed.

The desire of the miner may be to have a machine of light construction, but experience has shewn that the machine which has to serve as its own foundation must contain the necessary weight to allow sufficient power and strength to be produced, not only to overcome all the natural conditions connected with the seam, but to maintain the proper line of cut, and at the same time to excavate the dirt or coal at a minimum cost. When the roof is of a tender nature and experience shews that a specially quick

advance of the whole length of face is needed to "pluck" or "snatch," as it were, the seam from the effect of the overlying strata, it is essential that there should be an excess of power in the air-cylinders or electric motors. The machine also requires to be of the requisite strength, to withstand, not only the resistance due to working, but the sudden and unexpected strains which the natural conditions of the seam demand.

The writer thinks it better to carefully abstain from recommending any particular make of machine. Many papers have

FIG. 12.—HOLING TO A DEPTH OF 5½ FEET, AND ON THE WEDGES BEING WITHDRAWN, THE COAL FALLS IN CUBICAL PIECES, BEING OUTSIDE OF THE INFLUENCE OF THE ROOF-WEIGHT.

been read before mining institutes, and articles have appeared in mining journals describing rotary, bar, and chain coal-cutting machines, with their modifications and advantages, together with the cost of compressed-air and electric coal-cutting installations, which cannot here be referred to, as the estimates could only be approximate owing to the requirements being so varied. The cost of repairs and renewals, which are important items, cannot be mentioned here for the same reason.

In the writer's opinion it will be sufficient for the purpose of proving the arguments and statements now advanced, if an incision be made by a machine which will under-cut the required depth and thickness in the most suitable part of the seam or dirt. At the same time, it must be mentioned, that in order to make this communication of greater interest to the members, on the principle that illustrations often convey a better idea than printed matter, or that the eye will sometimes take in more than the ear, a number of photographs have been made of deep under-cut rotary machines. It will also be understood from an experience gained by the writer in the construction of over 150 machines in which the cut or incision varies from floor-level to a height in the seam of 3½ feet above the rail, and from an inspection of various seams of coal in the mining districts of Durham, Northumberland, Yorkshire, Lancashire, the Midland counties, and various steep mines in Germany, that many interesting details connected with the under- and over-lying strata, hardness of the material to be cut, area excavated, etc., could be introduced in this paper. But, the writer thinks it will be sufficient to mention that a coal-cutting machine should possess, among other qualifications, the following:—

(1) The machine must be capable of holing not only to a depth of 4 feet but to such a depth, say, 5, 6, or 7 feet as past experience of the working of the coal-seam by hand or pick may direct; and with the object of dispensing as far as possible with the use of explosives, at the same time to under-cut an area of coal sufficient to reduce the cost of cutting to a minimum.

(2) The cut must be of such a height in dirt, say 5 inches or more, as to cause a complete vertical fracture to take place between the excavated and solid coal, so that when a subsidence of the roof takes place the clearance made by the machine-cut is still sufficient to prevent the coal from being wedged or crushed (Figs. 12 and 13).

(3) The machine should be simple in construction, so that in case of accident an ordinary mechanic or colliery-fitter may repair it, and by having the fewest working parts liable to derangement or to undue wear-and-tear, frequent stoppages are prevented.

(4) Every part of the machine should be made of the very best and most suitable material, with the mechanical strains evenly distributed to ensure steady working; and of such strength that

if the machine is covered or buried by a fall of roof it may be dug out without injury.

(5) The machine should be of such dimensions and weight that it may be easily handled and transported by the men; and while working, should produce a minimum of vibration, even when subject to considerable resistance by the material to be cut, or when working on an uneven tram-road.

(6) Sufficient compressed air or electric power should be supplied to maintain the cutter-disc at a proper speed; and

FIG. 13.—HOLING TO A DEPTH OF 5½ FEET, AND ON THE WEDGES BEING WITHDRAWN, THE STRONG COAL FALLS AS ONE PIECE.

when working against exceptional resistance, it should be as noiseless as possible, so that the men in attendance may hear any indications of the giving-way of the roof.

(7) The arrangement of the stop-valve or switch should always be within touch of the attendant, so that in case of accident the machine can be instantly stopped.

(8) The rate of travel or cutting should be capable of adjustment while the machine is in motion, in order to suit the nature of the dirt or other material being holed; and an excess of power should likewise be available to overcome any débris which may fall and tend to wedge the cutting.

(9) The machine should be arranged to cut from left to right and *vice versa*.

(10) The edges of the cutters should be placed as nearly as possible equidistant from the centre, to ensure regularity of cut and to obtain equality of strains in the machine. The cutting-tools attached to the periphery of the wheel must be rigidly fixed, but in such a manner that they may be quickly changed or reversed. The cutters should be handy and portable easily repaired, and when too much worn for further use, leaving the least amount of waste-material.

FIG. 14.—MACHINE-HOLING AFFORDS MORE TIME TO THE STALLMAN FOR TIMBERING, PACKING, ASSISTING TO FILL COAL, ETC., THAN WHEN HOLING BY HAND, AND CONSEQUENTLY GREATER SAFETY.

(11) The cutters must clean out as much as possible of the small coal or dirt in the process of cutting, and prevent the same from being wedged and causing extra difficulties in the removal of the coal.

(12) An arrangement should be provided that the machine may, if required, cut its own way under the coal (Figs. 7, 8, 9 and 10).

(13) Some part or parts should be provided about the machine to act as a species of safety-valve in case of a heavy weight bury-

ing the machine, and such part should be the cheapest and quickest to renew.

With a machine possessing the foregoing qualifications, a good set of machine-men should preserve the straight line of face; keep the under-cut dirt clear from the cutting-wheel and so prevent it from again entering into the excavation; systematically set the timber (Fig. 16; and Fig. 20, Plate XXI.); leave each working-stall passed through in a safe condition, to enable the miners to fill coal immediately on commencing work in the following

FIG. 15.—STALLMAN FILLING COAL.

shift; besides carrying out other necessary detail work by which the output may be increased, the underground cost of production reduced, and the selling price of the coal enhanced in value by more cubical-shaped pieces with a reduced percentage of low-priced or small coal.

The following are some of the advantages which have actually resulted by the use of deep under-cut machines:—

(1) 170,000 tons of machine-got coal is being wrought per annum from one seam, 960 feet deep and 4 feet thick, the output per man varying from 5½ to 6¼ tons (Fig. 25). The standard getting-price is 1s. per ton; the total underground cost, 3s. 2½d.

per ton; and miners earned 9s. 10¼d. and fillers, 8s. per day (Appendix I., case B).

(2) From another seam, 1,500 feet deep and 3¼ feet thick, 4,200 tons of machine-holed coal is being got per week; the average output per man per day being 6½ tons; the standard getting-price, 11d. per ton; the total underground cost, 3s. 1¼d. per ton; and stallmen earned 10s. 9¼d. and fillers 7s. 8d. per day (Fig. 26, Plate XXI.; Appendix I., case C; and Appendix II.).

(3) In a seam 390 feet deep and 2 feet 10 inches thick; the output per man being 8½ tons, and the getting-price, 1s. per ton; the stallmen earned 10s. 5d. and the fillers 7s. 3d. per day (Figs. 27 and 28, Plate XXI.; and Appendix I., case A).

(4) Although most of the observations in the paper refer to mining deep coal, yet considerable advantages are at present being obtained by machines cutting in seams varying from 17 to 24 inches thick, and lying at a depth of 450 feet below the surface.

In some of these thin seams, the machines have been the means of prolonging the life of the colliery, utilizing a valuable plant, producing an improved sample of coal, with profit to the coal-owner, and enhanced wages to the workmen. Without the adoption of the coal-cutter, there are instances where old collieries only possessing thin seams of coal would have been abandoned, and a valuable plant sacrificed.

With respect to the relative advantages of the most suitable driving-power, the writer refers members to his paper written in 1899, on "The Comparative Advantages of Electricity, Steam and Compressed Air for Mining Purposes."* The writer believes, however, after 28 years' experience with compressed-air motors in underground work, that it is the only power that can be safely used in certain deep gaseous mines, where the natural difficulties are quite sufficient without the introduction of artificial dangers. On the other hand, there are many mines which can be worked safely and with advantage by electricity. The last few years have shewn that electrically-driven machines are able to cut an equal and occasionally a greater distance, under precisely the same conditions, as compressed-air machines. An electric installation on the multiphase system, erected about 4 years ago, for cutting a coal-face 4,500 feet from the shaft, has given complete satisfaction. There is little doubt that in the

* *Minutes of Proceedings of the Institution of Civil Engineers*, 1899, vol. cxxxviii., page 436.

near future, as central-stations for the supply of electricity are established, many forms of mechanical power will supersede hand-labour and many of these will be suitable for colliery-work.

At the present time, in the United Kingdom, coal got by machinery bears only a small proportion to the output by hand-holing. The last return shews only 3¼ millions, as compared with 52 millions in the United States of North America for almost a similar output, exceeding 209,000,000 tons. The next decade will undoubtedly mark a great increase in mechanical cutting. Coal-cutting machines made in this country have now passed the experi-

FIG. 16.—TIMBERING: PROPS, CHOCKS AND FACE-BARS SET IN A STRAIGHT LINE.

mental stage; and the opinion of a large number of workmen, based on ten years' experience with the machine, as compared with a similar experience with holing by pick, is in favour of machine-holing, inasmuch as higher and more regular wages can be obtained, less arduous work is required, combined with greater safety, and other advantages (Appendices I. and II.).

No difficulty has been experienced in training underground workmen to adapt themselves to holing by machine.

The machine-men work in an upright position as compared with the cramped one adopted by men using the pick and lying underneath the coal (Figs. 5 and 6). Over 1,100,000 tons of coal

have been got by machine, with four reported accidents, as compared with 315,000 tons got by hand or pick in the same seam for the same number of accidents. The short sprags (Fig. 11) are more easily set by unskilled men, this being partly due to the flat surface made by the machine-cut, as compared with the sloping coal-face made by hand-holing, against which the long sprags have to be skilfully set and properly stamped. It may also be mentioned that the triangular piece of coal, which the miner cuts away to obtain a greater depth of excavation, has to be replaced by a timber-prop (Fig. 5). Owing to the difficulty in doing this, or want of skill, a great number of accidents have resulted in past times.

Since the introduction of the machine with a deep under-cut, the use of explosives has been greatly reduced and in some instances abolished.

If the depth of cut be too small, the timber must be set very near the line of break (Fig. 28, Plate XXI.).

The coal-face is for a longer period more equitably protected from the action of the superincumbent weight, by allowing each square foot of seam to bear an equal pressure, instead of throwing the weight on projecting knobs or pieces of coal.

The thickness of the cut being sufficient to allow of a complete fracture, the excavated coal is removed from the influence of the roof-pressure which latter is duly taken up by settling on the pack-walls (Fig. 12). As a consequence of this, a much reduced percentage of small coal is produced, as compared with that holed with the pick.

A straight line of cut worked "end-on" prevents the workmen from slabbing the coal, altering or inclining the coal-face to bord-ways, and it also presents a surface of least resistance to the circulating air.

Assuming an advance of coal-face equal to 16½ feet, with a deep under-cut machine, the timber would in four weeks be set 12 times, whereas with a shallow under-cut machine, the timber, packing, rail-laying, etc. would for the same advance have to be set 21 times. The time thus occupied in setting timber, etc. would be available for filling coal (Figs. 14 and 15), whereby a larger output per man would be obtained, varying from 4½ to 10 tons per man per shift according to the conditions of the mine.

Owing to the lines of break being straight and fewer in number than the irregular and numerous fractures produced by hand-

holing, experience has shewn that the stall-gates and cross-gates are maintained with less expense, as the sides of such roads do not slab or easily fall.

In addition to the foregoing, other advantages may be summarized, namely:—(1) Fewer men are required at the coal-face, owing to the output per man being greater; (2) increased and more regular output per man; (3) less arduous labour; (4) better quality of coal; (5) greater tonnage from a smaller area of coal-field; (6) saving in timber; (7) reduced cost of production; and (8) minimum damage to the overlying seams and surface-property by a more regular settlement of the intervening strata; etc.

FIG. 17.—HOLING TO A DEPTH OF 7 FEET, WITH AN ELECTRICALLY-DRIVEN COAL-CUTTING MACHINE.

No hard-and-fast rule can, however, be laid down in mining operations, and it is more difficult to make laws for seams lying at a steep inclination than in the case of flat seams.

The writer wishes to mention his indebtedness to Mr. Henry Crowther, Leeds, who has made all the photographs; to his assistant, Mr. James Hopwood, for the electric light provided at long distances from the pit-shaft; and to the other officials connected with the West Riding collieries for the kind assistance that they have rendered in the production of this paper.

In conclusion, the writer wishes to explain that in the foregoing remarks he has endeavoured to keep before him the objects of this and other scientific institutions, namely, "the art of directing the great sources of power in Nature for the use and convenience of man," and he ventures to hope that the information introduced and the points raised with respect to straight lines in nature, straight lines of cut, straight lines of fracture, and straight lines of timbering, may in working certain seams of coal prove of service to the coal-owner, workman and consumer.

APPENDIX I.—Details of Seams cut by Machinery.

| | Case A. | Case B. | Case C. |
|---|---|---|---|
| | Ft. Ins. | Ft. Ins. | Ft. Ins. |
| Section of seam: | | | |
| *Roof:* Blue bind ... ... ... | * | — | — |
| *Seam:* Coal ... ... ... ... | 2 10 | 4 0 | 3 3 |
| Inferior coal and dirt ... | 0 9 | 1 3 | 0 9 |
| *Thill:* Spavin... ... ... .. | — | — | — |
| Depth below surface ... ... Feet. | 390 | 960 | 1,500 |
| Inclination of seam ... ... ... | 1 in 16. | Level. | Level. |
| Method of working ... ... ... | Longwall and packed gateways. | End-on longwall and packed gateways. | |
| Depth undercut by machine ... Feet. | 5½ | 5½ | 5½ |
| Thickness of cut ... ... Inches. | 5½ | 5 to 6 | 5 to 6 |
| Average distance, over 1 month, cut by machine per 8 hours shift ... Feet. | 180 | 226½ | 129 |
| Number of men employed with machine ... ... ... Men. | 3 | 3 | 3 |
| Average weight, over 1 month, got per man per shift ... ... ... Cwts. | 170 | 111¾ | 130½ |
| Weight of coal in tubs .. ... Cwts. | 5 | 8½ | 8¼ |
| Average number of tubs filled per man per shift ... ... ... Tubs. | 34 | 13 | 16 |
| Average wages, over 1 month, earned per shift: stallmen ... ... ... | 10s. 5d. | 9s. 10¼d. | 10s. 9¼d. |
| Average wages, over 1 month, earned per shift: fillers ... ... ... | 7s. 3d. | 8s. 0d. | 7s. 8d. |
| Conditions of work ... ... ... | Stallmen do timbering, filling, packing, making height, etc. | | |
| Special men drive and clean-up small coal and dirt after the machine .. | Paid datal wages. | | |
| Thickness of dirt taken up for packing Inches. | 4 | 15 | 7 |
| Diameter of props ... Inches. | 3½ | 6 | 5 |
| Width between props ... ... Feet. | 4 | 4 | 4 |
| Dimensions of chocks ... Inches. | Chocks are used where required. | 5 × 5 × 19 | 6 × 6 × 15 |
| Width between chocks ... ... Feet. | | 24 | 24 |
| Thickness of ripping ... Inches. | 24 | 36 | 28 |
| Width of ripping ... ... ... Feet. | 5 | 7 | 7 |
| Getting price: hand-holing ... ... | 1s. 11d. | 1s. 9d. | -- |
| Do. machine-holing... ... | 1s. 0d. | 1s. 0d. | 0s. 11d. |
| Illustrations, Plate XXI. ... ... | Figs. 27, 28. | Figs. 2, 3, 4, 5, 6, 11, 12, 13, 14, 15, 16, 20, 25. | Figs. 7, 8, 9, 10, 18, 19, 26. |

* Fig. 28. Plate XXI

APPENDIX II.—TABLE SHOWING COMPARATIVE COST OF WORKING A SEAM, 6 FEET THICK AND 240 FEET DEEP, BY HAND; AND A SEAM, 3¼ FEET THICK AND 1,500 FEET DEEP, BY COAL-CUTTING MACHINERY.

| | Working by Hand. | | Working by Coal-cutting Machinery. | |
|---|---|---|---|---|
| Thickness of seam | 6 Feet. | | 3¼ Feet. | |
| Depth of seam | 240 Feet. | | 1,500 Feet. | |
| | Standard Prices. | Including 57½ per cent. | Standard Prices. | Including 57½ per cent. |
| | s. d. | s. d. | s. d. | s. d. |
| Coal-getting | 1 5·50 | 2 3·56 | 0 11·00 | 1 5·32 |
| Bord-stalls | | — | 0 0·72 | 0 1·14 |
| Cutting | — | — | 0 3·06 | 0 4·82 |
| Cleaning | — | — | 0 1·40 | 0 2·22 |
| Ripping | — | — | 0 3·40 | 0 5·35 |
| Superintendence | 0 1·45 | 0 2·29 | 0 0·87 | 0 1·37 |
| Water | 0 0·74 | 0 1·16 | — | — |
| Horse-keeping | 0 0·41 | 0 0·65 | 0 0·15 | 0 0·23 |
| Hurrying | 0 3·23 | 0 5·09 | 0 1·58 | 0 2·49 |
| Bye-work | 0 1·41 | 0 2·22 | 0 0·53 | 0 0·83 |
| Main-roads | | | 0 0·90 | 0 1·42 |
| Totals | 2 0·74 | 3 2·97 | 1 11·61 | 3 1·19 |
| Average daily earnings: Stallmen | 5 9 | 9 0¾ | 6 10 | 10 9¼ |
| Average weight wrought per man per shift | 83½ cwts. | | 130⅛ cwts. | |

## EXPLANATION OF PLATE XXI.

FIG. 18.—Plan (from actual measurements) of a straight line of longwall coal-face in a seam, 3 feet 3 inches thick and 1,500 feet deep, holed by coal-cutting machines to a depth of 5½ feet. The lines of break, following the lines of each cut, are 5¼ feet apart, and the cleatage-planes run at right angles to the coal-face.

FIG. 19.—Section showing the lines of break, 5¼ feet apart, in the overlying strata, on line X Y of Fig. 18.

FIG. 20.—Plan of a longwall coal-face, with packed gateways, wastes, straight lines of timbering, etc., in a seam, 4 feet thick and 960 feet deep.

FIG. 21.—Plan of a long-wall coal-face, A B, 3,000 feet long, advancing 6 feet per week by hand-holing (this rate of advance is based upon actual experience) that only produces the same tonnage of coal as a longwall coal-face, C D, 1,092 feet long, advancing 3 cuts or 16½ feet per week by machine-holing. The same produce, 2,573 tons per week, is obtained from each length of coal-face, A B or C D, but there is a greater percentage of large coal where the holing is cut by machines, and a greater percentage of small coal where the holing is cut by hand. With hand-holing, 1,908 feet of extra length of coal-face, E F, is subjected for a longer time to the effects of the superincumbent pressure, resulting in crushed coal, and increased cost of gateways, timber, rails, etc.

FIG. 22.—Section of a seam, 3¼ feet thick and 1,260 feet deep, showing the lines of break (from actual measurements) resulting from hand-holing.

FIG. 23.—Plan, on line A B of Fig. 22, showing the irregular line of break, resulting from hand-holing similar to the line, G H, shown in Fig. 24.

FIG. 24.—Plan, on line C D of Fig. 22, showing the sinuous line of holing, G which is produced by hand-labour: the consequent irregular line of br E F, is shown in Fig. 23.

FIG. 25.—Plan of the actual workings in a coal-seam, 4 feet thick and 960 deep, made during the years 1892 to 1901, showing the alteration in method of working from longwall retrograde with roadways through c pillars to longwall advancing with packed gateways.

FIG. 26.—Plan of the actual workings in a coal seam, 3¼ feet thick and 1,500 deep, by coal-cutting machines holing to a depth of 5½ feet.

FIG. 27.—Plan of the actual workings in a coal-seam, 2¾ feet thick and 390 deep, showing coal-faces which have advanced 467 and 533 feet per ann respectively by the use of coal-cutting machines.

FIG. 28.—Section showing the lines of break (from actual measurements) result from machine-holing in the same seam as Fig. 27.

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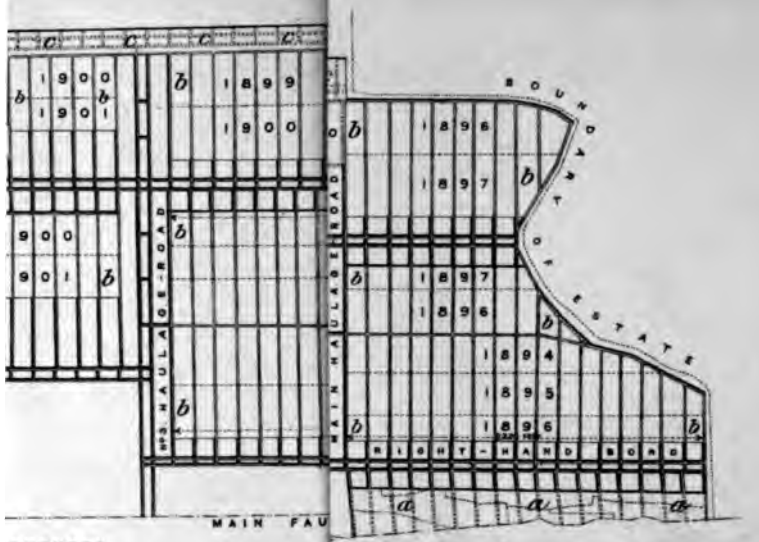
The PRESIDENT (Mr. John Gerrard) said that Mr. Garforth h shewn the members that coal-cutting by machinery could be do and was being done, with less arduous labour to the workers, a with increased safety. Mr. Garforth had given convincing figu proving that the working of coal by machinery resulted in increased output and increased earnings to the workers, and fact that this was not generally known might explain some of th prejudice which existed in the minds of colliers against coal-cutting machinery. The reduction of the cost was not, to hi mind, the only question, but increased output and increased safety were two points to which they would have to look in the future. They were not to be beaten by Americans; what had been done in America could be done here, and he felt sure that the day would quickly come when it would be better done.

Mr. G. BLAKE WALKER said that in all mining operations they were constantly working to a greater or less extent, all of them, by rule of thumb, and the general laws which governed their opera tions were very imperfectly understood. Consequently, they blundered, and carried out their work far less successfully than they would do, if their knowledge were more accurate. Although he had been connected with coal-cutting work as long as most people in the Midland district, and although many of the facts which Mr. Garforth had placed before the members had been forced upon his own observation, yet, aided by the photographs which had been thrown upon the screen, he had more clearly

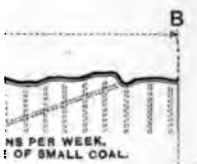



ERENCES.

KED BY HAND-HOLING PRIOR
DUCTION OF COAL-CUTTING

ROGRADE.

H PACKED GATEWAYS.




NS PER WEEK.
OF SMALL COAL.

A LENGTH OF COAL-FACE,
ED FOR A LONGER TIME
OF SUPERINCUMBENT
TING IN CRUSHED COAL,
COST OF GATEWAYS,
R, RAILS, ETC.

*, 1,200 Feet to 1 Inch.*



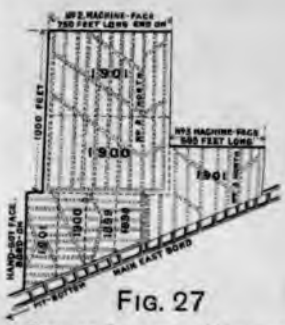



FIG. 27

PLAN OF LONGWALL WORKINGS.

*Scale, 1,200 Feet to 1 Inch.*

ONGWALL FACES.

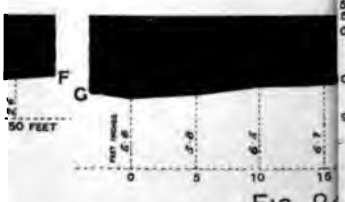



FIG. 2

*le, 16 Feet to 1 Inch.*

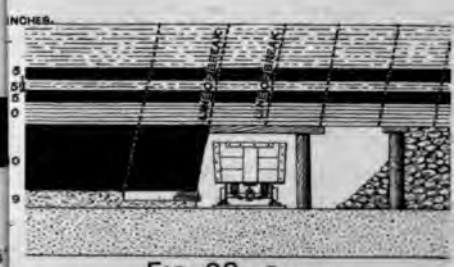



FIG. 28.—SECTION

*Scale, 8 Feet to 1 Inch.*

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realized some of the general principles which underlaid the whole question. He was sure that the members would feel deeply indebted to Mr. Garforth for his paper, and for the way in which he had worked at this problem for twenty years past. Mr. Garforth's success, which had cost him and his company much money, had paved the way for other people now to step in and to take advantage of his experience gained by work done, without having to cover the preliminary cost. They had had to fight and struggle against an extraordinary amount of prejudice on the part of the miners, and the reason that coal-cutting had not been taken up in the past as it should have been, was that it had been made almost impossible to derive any pecuniary benefit from coal-cutting machines. It was only within the last five or six years, as far as he knew, that the financial side of coal-cutting had been satisfactory. The difficulties, with which they had had to contend, had for many years made coal-cutting a doubtful matter as regards finance; but henceforward, he believed that those who adopted machinery would reap a considerable financial advantage. They all desired that Mr. Garforth's firm might be very successful and that coal-cutting generally might have a great future in this country. He had great pleasure in proposing a hearty vote of thanks to Mr. Garforth for his paper.

Mr. Isaac Hodges seconded the resolution, which was unanimously adopted.

# THE MIDLAND INSTITUTE OF MINING, CIVIL AND MECHANICAL ENGINEERS, AND THE MIDLAND COUNTIES INSTITUTION OF ENGINEERS.

JOINT MEETING,

HELD AT THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD, JUNE 14TH, 1902.

MR. JOHN GERRARD IN THE CHAIR.

The following gentlemen were elected to the Midland Institute of Mining, Civil and Mechanical Engineers, having been previously nominated:—

MEMBERS—

Mr. WILLIAM MCDONNELL MACKEY, Consulting Chemist and Chemical Engineer, Victoria Chambers, South Parade, Leeds.

Mr. CHARLES TINKER, Colliery-owner, Meal Hill, Hepworth, near Huddersfield.

STUDENT—

Mr. HERBERT RAMSDEN, Mining Apprentice, Edgemoor, Rutland Road, Harrogate.

## DISCUSSION OF MR. W. E. GARFORTH'S PAPER ON "THE APPLICATION OF COAL-CUTTING MACHINERY TO DEEP MINING."*

Mr. W. E. GARFORTH repeated part of his paper, and the illustrations were also reproduced.

Mr. G. E. COKE, in moving a vote of thanks to Mr. Garforth, remarked that he had shewn that by properly keeping a careful record of work that had been done they could obtain most valuable information: but he (Mr. Coke) feared that many managers of collieries never realized the importance of keeping accurate records.

The CHAIRMAN (Mr. John Gerrard), in seconding the vote of thanks, said that it had been a delightful treat to see on a screen what they might not see though they entered a mine hundreds of times; and information on the subject of fractures, etc., which it was most desirable they should have, had been well put before the members.

* *Trans. Inst., M.E.*, 1902, vol. xxiii., page 311.

Mr. MAURICE DEACON (Sheepbridge Iron-works) said that Mr. Garforth had covered so vast an extent of ground that the work of criticizing such a paper was extremely difficult. Mr. Garforth had stated that a seam which could be worked "longwall by hand," could be worked "longwall by coal-cutting machine," but on that point, he differed from Mr. Garforth. Coal-cutting machines were, no doubt, extremely applicable and useful under certain conditions, but there were many conditions within his experience, in which coal-cutting machines could not have been economically or advantageously applied. There were many cases where the condition of the thill, or of the roof, would not admit of coal-cutting machines being used; and there were other cases where the holing was of such a character that, *per se*, a coal-cutting machine could be of no possible use. It could not be of any use in seams, which practically get themselves. In thin seams, and, in fact, in thick seams where the roof would stand, and where the holing was sufficiently hard to warrant the use of machinery, there were, no doubt, great advantages secured by the use of coal-cutting machinery—that was to say, in the working of long, straight faces. It was absolutely necessary, in order to work the machine successfully, that there should be long, straight faces, and the machine got credit for them, and there were a great many other advantages for which the coal-cutting machine got credit. With regard to cost, he adopted coal-cutting machines many years ago, spread it in all directions, and in some instances he had saved as much as 1s. per ton in the price paid for getting; but there was another charge to add to it which had been a very serious one, and had amounted to 5d. or 6d. per ton, namely:—The cost of machinery, labour, and the proportion of the cost of mechanical appliances, boilers, steam, etc., so that the whole saving of labour could not be credited to the coal-cutting machine. Nevertheless, where conditions were favourable, great benefits were to be derived from the use of coal-cutting machines. Taking the question in the gross, Mr. Garforth had dealt with it in a most able manner, and the members ought to be extremely obliged to him for the great trouble that he had taken in putting his facts before them.

The resolution was cordially approved.

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Mr. G. A. LONGDEN's paper on "Changing Head-gears at Pleasley Colliery" was read as follows:—

# CHANGING HEADGEARS AT PLEASLEY COLLIERY.

By G. A. LONGDEN.

*Introduction.*—The headgears at both of the pits at Pleasley colliery were erected 23 years ago. The front legs were cast-iron columns fastened to pitchpine main legs by wrought-iron lattice-frames, nearly semicircular in shape, and two cross-girders fastened to these frames carried the detaching-hook plates. The main legs were 16 inches square at the bottom and tapered to 12 inches square at the top, the height was 60 feet, and the difference in width (being only 7 feet less at the top than the bottom) made them appear to be nearly vertical. The back legs were also made of pitchpine, 18 inches square at the bottom, tapering to 12 inches square at the top, and were placed parallel; shoes resting on large stones in the wall of the engine-house received the lower ends, and two cast-iron columns supported the middle of the back legs. The condition of the woodwork had deteriorated, and it was decided to erect new headgears at each pit.

Both shafts are used for coal-winding for 9 hours per day, so that one of two methods had to be adopted:—(1) To remove the existing headgear, and to build a new one in position while winding coal at the other shaft for two shifts in each day; or (2) to build the new headgear at a distance from the pit-top, and to move the complete structure into its desired position.

*Upcast Shaft.*—It was decided to build the headgear, in position, at the upcast shaft, and at the same time to erect a more powerful winding-engine and boilers. This work occupied several months, during which the downcast shaft was worked by double shifts, work being thus found for the men employed in the upcast shaft. A capstan-engine and small pit-frame were erected for use, in case of accident, at the downcast shaft, and the engine proved extremely useful in dismantling the old and erecting the new headgear. These alterations to the winding-engine and headgear at the upcast shaft were not completed until May, 1900.

*Downcast Shaft.*—In the meantime, the condition of the back legs at the downcast shaft became serious, and it was decided to proceed with the erection of the new headgear, as soon as possible. The underground arrangements and the surface-plant precluded two coal-working shifts being employed at the upcast pit, while the new headgear was being erected at the downcast pit; and it was decided to build it in line with the engine-house and shaft, but at a distance from the shaft, in order that coal-drawing could be continued. As much ground would have to be removed, in order to allow the top of the frame-girders to rest on the same level as the flat-sheets, it was decided to raise the pit-top, together with the tram-roads, weighing-machines and cabin, by 15 inches, as being the readiest and least costly operation.

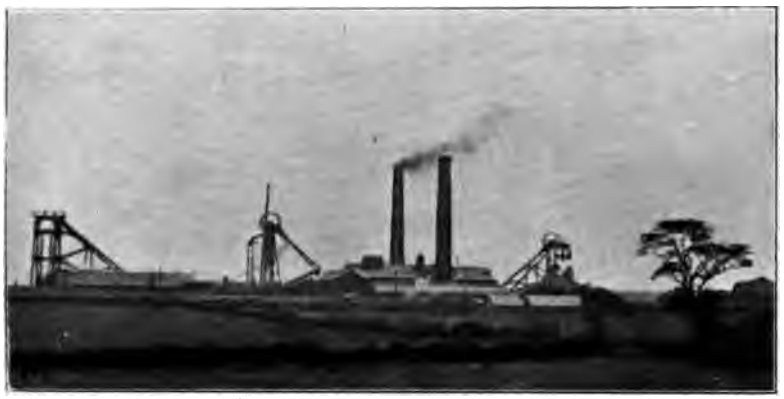

FIG. 4.—NEW HEADGEAR, BEFORE ITS REMOVAL TO THE DOWNCAST PIT.

The headgear was built upon long girders, 15 inches deep, so that it could be rolled into position as soon as the old headgear was removed. It may be mentioned that it was impossible, in either case, to erect the new headgears over the existing ones, because the new headgears were to be erected of the same height as those already existing. The new headgear was erected about 180 feet in front of the shaft (Fig. 1, Plate XXII., and Fig. 4), and the contractors commenced to erect the headgear on March 25th, 1901. To facilitate the removal of the pulley-wheels, a pitchpine derrick, 91 feet long, was raised on May 17th, 1901, three guy-ropes were fastened to steady the derrick, and a fourth guy-rope was fastened to a crab, to enable the top to be moved and thus assist

in raising and lowering the pulley-wheels. Pulley-blocks were fastened to the top of the derrick, and a flexible steel-rope, $\frac{7}{8}$ inch in diameter, was connected to a steam-winch. During the evenings of the following week, strong gangs of workmen were engaged in clearing the ground.

FIG. 5.—REMOVING THE NORTH SIDE WINDING-ROPE FROM THE OLD HEADGEAR.

On Friday, May 25th, 1901, work at the downcast shaft ceased at 1·20 p.m., and all the men were out of the pit by 2·15 p.m. The wooden conductors were cut above the stays, the cage-prop levers were removed, and the props were fastened back. The rope on the north side of the pit was removed (Fig. 5) and coiled into a wagon, the rope on the south side was wound on to the drum, and both cages were left in the pit-bottom. The pulleys, and their pedestals and brasses, together with the detaching-hook plates, were then lowered to the ground.

The derrick was then inclined towards the engine-house, and the lower block was fastened to a timber cross-piece, fixed under the back legs about 6 feet from where the back legs were joined to the main legs. The back legs were then cut through, with cross-cut saws, above this cross-piece, and the blocks were then tightened

by the steam-winch; but as two of the six cuts had not been cut through at the proper angle, instead of the back legs being lifted away, they fastened themselves. As it was almost dark by this time, the attempt to drop the old headgear was abandoned for that night.

FIG. 6.—BACK LEGS CUT THROUGH AND RAISED APART FROM THE MAIN LEGS OF THE OLD HEADGEAR.

Meanwhile, gangs of workmen cleared away the roads, gantries, weighing-machines, and cabin from the pit-top, and laid a road upon which the new headstock could be rolled, and this work was not completed when daylight returned. A piece was then completely cut out of each back leg and stays. A haulage-rope, ¾ inch in diameter, was then fastened to the main leg and another to the wrought-iron half-moon girder on the south side, and both of these ropes were attached to the rails of a siding by snatch-

blocks, which could be pulled by locomotives. All being in readiness, the back legs were raised by the winch (Fig. 6), then both locomotives pulled as nearly together as possible at the ropes, and the front and main legs fell forward to the ground. It had been hoped that by pulling from the side, it would have fallen in that direction, but the heavy iron columns lifted up the lower ends of the wooden legs, and the whole mass fell at 6·40 a.m., in a direct line towards the new headgear, and caused considerable delay, as the whole of the wooden headgear had to be removed before the new one could be moved into position.

The road used for moving the new headgear into position consisted of two lines of boiler-plates, *a*, 3 feet wide, laid on the ground, above these two pitchpine baulks, *b*, 12 inches square, were placed. Tram end-plates, *c*, 2 feet wide by ¼ inch thick, were fixed, on these baulks, upon which the rollers would run, as it was thought that if any roller received any excess of weight it would make a hollow in the timber, into which the following rollers would probably stick (Figs. 2 and 3, Plate XXII.). The cast-iron rollers, *d*, 6 inches in diameter, with a hollow core 2 inches in diameter, were 3½ feet long, and 50 were used.

The morning of May 26th was occupied in clearing away the old headgear and in re-laying the road, which had been disturbed by the fall of the old headgear. A rope was taken from the winch to a block at the centre of the engine-house, and fastened by two chains round the bottom of the main vertical legs. The new headgear was erected on oaken blocks, 6¼ inches square, and these had been replaced by about 40 rollers evenly distributed, and rather more than 4 feet apart.

By 11·40 a.m., the bank was cleared; and with the assistance of over 100 men and the steam-winch, the new headgear, 112 tons in weight, then began to move forward, a few feet at a time, so as to allow of the rollers being brought from behind and placed in front. By 1·45 p.m., the back-end of the headgear was nearing the first foundation-stones (Fig. 7), and about 1 hour was spent in laying the road to the engine-house.

Fig. 2, Plate XXII. shews that the stones projected about 4½ inches above the line of the top of the road, thus leaving only 1½ inches of space between the top of the stones and the bottom of the moving girders, and this necessitated the baulks being cut on each side of the stones so as to allow the rollers to be removed

from behind and replaced in front of the stones; and instead of 6 inches, the diameter of the rollers, the headgear had only to be lowered 1½ inches to the permanent foundation when the rollers were removed.

When the road to the engine-house was complete, the last stage of the journey of the headgear was commenced. The road

FIG. 7.—NEW HEADGEAR IN MOTION TOWARDS THE DOWNCAST PIT.

on the south side sank about 1¾ inches, under the weight of the headgear, and the girders touched the foundation-stones. Two 40 tons hydraulic jacks were placed under each side of the girder, and the headgear was raised slightly, so as to allow of plates ¼ inch thick being placed under the rollers in order to raise the girders above the foundation-stones. Considerable delay ensued, and the headgear was not placed in its position until 4·15 p.m., 4½ hours being occupied in the traverse of 180 feet.

The headgear was then 4¾ inches from its correct position, and the 40 tons hydraulic jacks were placed on each side of the longi-

tudinal girders, which were raised so as to allow the rollers to be removed. Workmen continued clearing the road and removing the old headgear throughout the night, and by 8 p.m., the south side pulley was placed in position: but owing to a difficulty in fitting the brasses to the new pulley and shaft, the north side pulley was not set until 11 a.m. on Sunday morning.

FIG. 8.—NEW HEADGEAR AT THE DOWNCAST PIT.

The whole of Sunday was occupied in levelling the headgear, and lining through so as to determine its correct position: and it was found to have settled evenly upon the foundation-stones, which had been previously levelled. The headgear was pushed into position by the hydraulic jacks, holes, about 9 inches deep, were drilled into the stones, and the bolts were run in with molten lead; and then it was fixed as nearly level as possible (Fig. 8).

Monday was spent in clearing away the old pit-top frame carrying the cage-props, and in lowering and removing the derrick. On Tuesday, the erection of the new weigh-cabin was commenced, new baulks were fitted for the cage-props, as the old ones

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To illustrate Mr. G. A. Longden's Paper on "Changing Headgears at Pleasley Colliery."

Vol. XXIII. Plate XXII.

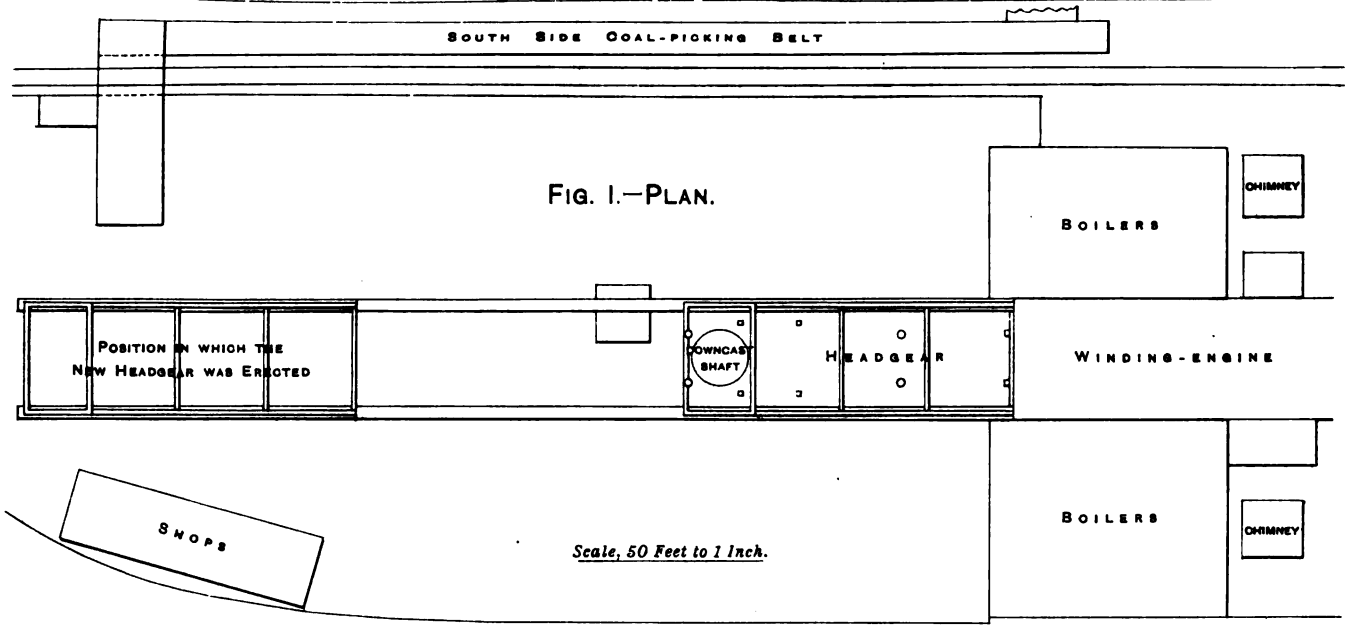


Fig. 1.—Plan.

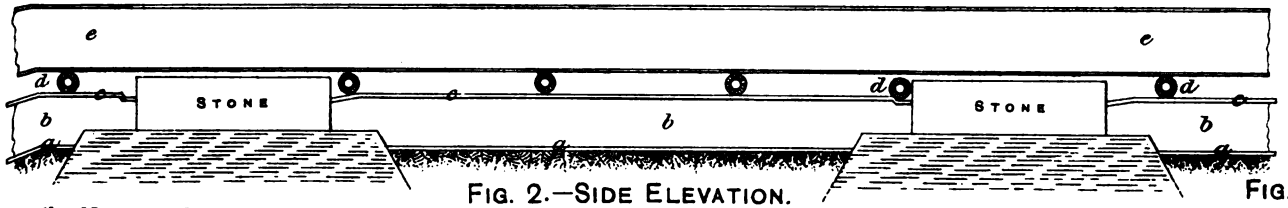


Fig. 2.—Side Elevation.

Scale, 4 Feet to 1 Inch.

Fig. 3.—Cross-section.

Vol. XVI, Plate XIV.

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were defective, and the cage-props were fixed in position, giving the level to which the tram-roads round the pit-top should be laid. On Wednesday, the north side winding-rope was replaced, both ropes were fastened to the cages, the cage-conductors were joined to the new headgear, and the pit-top roads and decking arrangements were commenced. On Thursday, water was drawn from the cistern in the pit-bottom, and the tram-roads, weighing-machines, and decking arrangements were proceeded with.

This method was very expensive for labour, and the extra frame-girders carrying the headgear enhanced the cost; but, on the other hand, it was impossible to allow the downcast pit to stand for 2 months, while the old headgear was being removed and the new one erected on its site.

The actual time occupied in removing the old headgear and in placing the new headgear into position, and in fitting the pulleys, was about 48 hours, from Friday afternoon, May 25th, to Sunday afternoon, May 27th, 1901.

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A cordial vote of thanks was accorded to Mr. G. A. Longden for his interesting paper.

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## SINKINGS AND BORINGS.

The CHAIRMAN (Mr. John Gerrard) said that at a meeting of the Council of the Midland Institute of Mining, Civil and Mechanical Engineers it had been decided to begin to collect sections of the strata sunk or bored through, in order to compile a volume of sections of strata, and a committee was appointed to compile the volume. He invited the Midland Counties Institution of Engineers to co-operate in this work, and to appoint a committee to work jointly with them.

Mr. G. E. COKE stated that he would bring the question before his Council, and he hoped that they would adopt so very useful a suggestion.

# THE INSTITUTION OF MINING ENGINEERS.

## GENERAL MEETING,

HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON, MAY 29TH, 1902.

MR. J. S. DIXON, PRESIDENT, IN THE CHAIR.

## CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, GLASGOW, 1901.

The Report of the Delegate (Prof. H. Louis) representing the Institution was read as follows:--

TO THE PRESIDENT AND COUNCIL OF THE INSTITUTION OF MINING ENGINEERS.

NEWCASTLE-UPON-TYNE, MAY 1ST, 1902.

GENTLEMEN,

I regret that, being abroad at the time, I was unable to attend the Conference of Delegates. However, nothing was brought forward that could interest the members of this Institution. The matter of copyright was referred to the Council of the British Association which will co-operate with other scientific societies if the Copyright Bill be again brought forward.

The following list comprises the chief papers that might be of interest to the members:—

"Report of the Committee on Underground Temperatures."

"Report of the Committee on Life-zones in the British Carboniferous Rocks."

"Notes on the Output of Coal from the Scottish Coal-fields." By Mr. R. W. Dron.

I am, Gentlemen,

Yours obediently,

HENRY LOUIS.

The PRESIDENT delivered the following address:—

# PRESIDENTIAL ADDRESS.

By JAMES S. DIXON.

In delivering an address to The Institution of Mining Engineers, the difficulty is to find a subject which has not already been exhausted by the many distinguished men who have preceded me in this chair.

I confess at once that my experience as a mining-engineer has been very much confined to my native Scotland, although I have visited some of the mining-districts of England and America, and have there inspected a few of the more important coal- and other mines. Mining in Scotland is prosecuted in a field, which to a considerable degree presents most of the difficulties that have to be solved by the mining-engineer: in many of its districts the coal-seams are much faulted, and occur at every inclination from level to the perpendicular and often are heavily watered; and I propose to apply myself to a somewhat general description of the practice which there obtains, together with some other remarks more or less relevant thereto.

The principal Carboniferous strata of Scotland lie in what may not inaptly be termed the "waist" of the country—the contour widening out both to the north and south. It stretches between the firths of Forth and Clyde in a north-easterly and south-westerly direction, for a length of about 70 miles and has a varying width of about 20 miles. This area is not a continuous coal-field, but is much broken up into basins and areas containing coal-seams; accompanying these are numerous beds of blackband and clayband ironstones, fire-clays and oil-shales, all of which have been extensively worked. The coal-bearing strata of Scotland chiefly occupy two separate geological horizons, namely:—The Upper series underlying the red sandstones and the Lower series underlying the white sandstones of the Millstone Grit. Below the Lower or Carboniferous Limestone series the Calciferous Sandstones occur, containing some inferior coal-seams and the oil-shales, which are extensively mined in the Mid-Calder and other districts.

Both the Upper and Lower series of coals contain many seams of superior thickness and quality, and it may be said that in the west of Scotland the Upper coal-seams are the most valuable, whereas in the east the reverse applies. In consequence, in the west, the greater part of the output at present is from the Upper, and in the east, from the Lower or Limestone Coal-measures.

While the coal-field, in most districts, has been extensively tested and proved by sinkings and bore-holes, and is thus fairly well known down to a depth of about 1,500 feet, below that depth there are large areas of the Lower series that may be described as a concealed coal-field yet to be proved. It is questionable if there be much coal exceeding a depth of 4,000 feet, which was assumed, by the Royal Coal Commission of 1871 (after exhaustive enquiries), to be within reach of mining without special appliances. I understand that that depth had now been nearly approached in a coal-mine in Belgium. The greatest depth to which coal-mining has been carried in Scotland is about 2,700 feet at Niddrie, near Edinburgh.

In the coal-fields of Scotland, there are about 460 collieries at work and the output for last year was 32,796,510 tons, showing an average output of about 70,000 tons for each; but some are small concerns, as individual pits are producing as much as 387,000 tons per annum.

The deepest vertical shaft in the eastern district is 1,650 feet, and in the western 1,470 feet, although as before stated, partly by vertical shaft and partly by driving to the dip in the seam, a depth of 2,700 feet has been reached. Several mines are now being sunk to a depth of upwards of 1,800 feet.

Exploring for coal or minerals, at shallow depths, is chiefly done by a chisel hung by rods from the end of a beam and made to reciprocate vertically by manual labour. In the above circumstances, with experienced men, this method is fairly accurate, but only the dust of the cut strata is recovered in the form of mud. For greater depths, the usual method is by the diamond-drill by which, if the strata be hard enough, a solid core of them is brought to the surface: but coal of fine quality has not enough cohesion for this, so it is brought up in smaller pieces, though usually in sufficient quantity to afford an accurate idea of its quality. One great advantage in recovering

cores of strata is that they show the inclination of the beds by the planes of stratification. Lately, several bore-holes have been put down by diamond-drills to depths of over 2,000 feet: one of these 2,130 feet in depth, was effected in 12½ months. It was begun at 6¼ inches and finished at 4½ inches in diameter, and pierced great thicknesses of trap and other hard rocks. Bore-holes are now being made, which are anticipated to reach depths of between 3,000 and 4,000 feet.

The almost universal practice in Scotland has been to sink rectangular shafts and to line them with wood. Probably, this arose from the fact that, until after the middle of last century, mine-shafts were never expected to continue in use for more than a few years. This arrangement lends itself to the division of the shaft into convenient spaces for winding, pumping, ventilation, etc., and where, as in some parts of Scotland, almost at every shaft of a colliery, water has to be pumped, the pipes can be conveniently fastened in the shaft. Formerly shafts were usually adapted for single cages and pumps, and were made from 12 to 14 feet long by 5 to 6 feet wide. As larger cages for increased outputs became desirable, the length of the shafts was increased, the usual practice being to set two tubs side by side on each deck. The modern practice is to increase the width, making the arrangement more like that of a circular shaft. An advantage of this is that the widths of the pit-bottom and the delivery-rails at the top are much reduced, and the whole better adapted to modern systems of handling the traffic at both top and bottom. The most recent and deeper shafts are being sunk of sufficient size to enable four tubs to be placed on each deck of the cages.

Ventilating furnaces being practically obsolete, wood-lined shafts are not so objectionable in respect of danger from fire, as formerly, and when the wood is constantly saturated with water, it is still in good preservation after more than fifty years. However, where it is only partly wet and alternately dry, the very best wood gives rise to trouble, and it may be anticipated that as shafts require to be sunk to greater depths and to work larger areas for longer periods, circular brick or concrete-lined shafts will become more general. The wooden lining of the shafts is usually 3 to 6 inches in thickness, the end-bars being notched into the side-bars, and the corners supported by tri-

angular-shaped pieces of timber about 6 inches on the face. Strong wall-plates are nailed to the side-bars, and between these, across the shaft at intervals according to the nature of the strata, buntons are placed to keep the sides of the shaft at the proper distance apart, and are afterwards utilized to hold the guides for the cages, which are chiefly made of wood, although iron rails are also used. The buntons are held in position by pieces of wood run up their sides, nailed to the wall-plates, and by distance-pieces between.

Sinking through mud or other soft surface-material is usually accomplished by the aid of a shield made of iron-plates with a cutting-edge: this is hung from logs across the top of the shaft, and lowered as the sinking progresses, the wooden lining being inserted as the shield descends; and until the bottom of the soft material is reached, the lining is hung by iron bands, the corners being held together by strong angle-iron bars. By means such as these, but varied according to circumstances, considerable depths of very bad surface-material have been sunk through. In special cases, circular iron, concrete and brick cases, have been used with a cutting-shoe at the bottom.

Every mining-engineer is aware that the chief difficulty in sinking is from water. Large flows have to be dealt with in some sinkings, as in many parts of the coal-field the strata are largely composed of open-fissured sandstones and porous soils, through which every shower of rain finds its way into the strata and often to the coal-workings at very considerable depths. Formerly, water in sinking was got rid of by pumping-engines placed on the surface, pipes and wooden rods being travelled in the shafts, with sliding suction-pieces, and many other devices. Now, sinking-pumps are widely adopted, the engine and pump being slung in the shaft and lowered as the sinking progresses. It is well not to overtax these appliances in the matter of head, and to insert temporary forcing pumping-engines, into lodgments cut in the side of the shaft, to which the slung-pumps in the pit-bottom discharge their water. For short lifts, pulsometers are used to advantage, either in sinking or emptying old workings of accumulations of water. With such modern appliances, large flows of water can be dealt with and good progress made. Electric sinking-pumps are now being introduced, and will possess many advantages over those driven by steam.

In Scotland, the water encountered in the Carboniferous strata, either from their porous nature or through the fractures made by working the coal, in most cases finds its way into the mine. Tubbing-back water in shafts is therefore almost unknown; and, in consequence, permanent pumping-plant has usually to be erected. The general practice, the result of experience, is to place the engine on the surface, and to actuate the pumps in the shaft by wooden rods. The pumps are usually of the twin-plunger type, with two plungers at each station, generally placed about 400 to 500 feet apart vertically. The rods are continued down past the intermediate to the last set of pumps at the bottom of the shaft, and are arranged so that their weight only slightly exceeds that of the water in the columns of pipes, so as to make sure that the work is done in tension. This arrangement obviates any necessity for counter-balance beams and other similar contrivances, the whole being equally balanced in the shaft, the weight of the rods descending being exactly that of those ascending. Pumps of this type, with double plungers up to 23 inches in diameter by 12 feet stroke, are in constant work forcing quantities of water up to 1,500 gallons per minute from depths of 1,200 to 1,500 feet. Compound-condensing engines are now generally employed, with high- and low-pressure cylinders, either horizontal or vertical, with a steam-pressure of 80 to 100 pounds per square inch. The reciprocating motion of the pump-rods is effected by the intervention of quadrants or bell-cranks placed at the top of the shaft, and these are actuated either through toothed gearing or direct from the piston-rods of the engines. The advisability of adopting either of these methods depends on the weight of water to be raised. There can be no doubt as to the economy of a comparatively high piston-speed, such as can be commanded by the introduction of gearing, and cylinders of much less size are sufficient for the same work. The ratio of the gearing is usually about 6 to 1, the pinion being about 3 feet and the wheel about 18 feet in diameter. Engines of this type are at work with weights in the shaft up to 60 tons, but for weights exceeding 50 tons the direct-acting principle is to be recommended. From some trials of these engines and pumps forcing water against heads varying between 750 and 1,440 feet, it was found that the work done per pound of steam by three large direct-acting engines

averaged 48,000 foot-pounds, as compared with 56,500 foot-pounds by three of the largest class of geared engines, showing an economy of 17¾ per cent. in favour of the latter. These engines showed mechanical efficiencies between 85 and 92 per cent. in relation to the power exerted and the water pumped; and they consumed from 28 to 41 pounds of steam per indicated horse-power in the engine, and from 32 to 48 pounds per horsepower in the water raised. In Cornwall, the duty of pumping-engines is reckoned as so many millions of pounds of water raised 1 foot high per hundredweight of coal consumed, and 50,000,000 to 60,000,000 pounds is considered to be a satisfactory result. Comparing the above engines with this standard, and assuming that, in Cornwall, first-class steam-coal was used with good boilers, evaporating say 10 pounds of water per pound of coal or 1,120 pounds per hundredweight, the direct-acting engines above-mentioned gave a duty of 53,760,000 pounds and the geared engines a duty of 63,280,000 pounds. As the tests were made on every-day practice, the results seem to be fairly satisfactory.

Underground forcing pumping-engines are also much used, but the leading of steam down deep shafts has been found to entail many disadvantages, and underground boilers are considered objectionable.

Hydraulic pumps, actuated by a column of water in pipes passing from the plungers of a steam-engine aboveground to the plungers of a pump underground, are largely employed. With a reciprocal motion of the water-column, these pumps are not economical, and give rise to shocks and trouble. An arrangement, by which there is a continual flow of water in one direction, obviates these objections and seems to work satisfactorily.

Winding-engines are usually of the horizontal, coupled and direct-acting type, and for the moderate depths of Scotch mines and with steam-pressures of 80 to 100 pounds per square inch, as now generally used, comparatively small quick-running engines are employed.

Mechanical ventilation by fans, either exhausting or forcing, is now universally adopted.

Haulage of coal on the underground roads, owing to their greater lengths, is of increasing importance; and it is now carried to great perfection by the single-rope, tail-rope and endless-rope systems. The first is applied on dipping-roads where the

gradient is such as rapidly to take out the slack rope by the descending empty tubs; and this system is found convenient, in the above circumstances, where a number of benches or side roads have to be drawn from. Tail ropes are generally adopted in roads with bends, and where from the nature of the roof it is desirable to curtail the width of the road, one set of rails being sufficient. The most universal system is by endless ropes: to avoid tubs leaving the rails and many other evils associated with high speeds, it is found advantageous to move the endless ropes slowly, at from 1½ to 2 miles an hour; and, the tubs being attached singly to the ropes, it is a question of their number to produce a given quantity. There are instances where one rope moving at 1¾ miles per hour is delivering upwards of 800 tons in 8 hours. The motive powers generally employed are steam-engines on the surface, with either the haulage-ropes led down the shafts and into the workings; the power transmitted down the shafts by band-ropes actuating machinery there, from which separate ropes are led into the workings; engines placed underground and driven by steam or compressed air, electricity, and gravity. In many collieries in Scotland, all these systems can be seen doing excellent work. Electricity is making rapid strides, and is found very convenient where the power has to be transmitted for considerable distances underground. It tends to reduce the cost of maintenance to have few main roads leading through the waste from the shaft, and from the inside ends of these, haulage-roads can be branched in several directions concentrating the traffic at what may be termed central-junctions on the main-roads; and at such points, electric haulage-plants can be easily placed. As a rule, the motor-house can be ventilated with fresh air, and there are few mines in Scotland in which a well constructed continuous-current electric-motor with carbon-brushes or an alternating motor is not safe.

The best of all haulage-powers is gravity. I do not so much mean high-speed inclines with trains of full tubs coming down, drawing up trains of empty tubs, as slow-motion ropes with tubs attached at regular intervals. These can be arranged to work round bends on the roads, with varying gradients or parts of the road level or flat, and other parts sufficiently steep to give the requisite power by gravity. With the tubs generally in use, it is found that an average gradient throughout the length of the

road of 1 in 18 is about the least that can be relied upon to overcome the weight of the empty tubs, friction, etc. In this system it is absolutely necessary that the tubs be put on the rope at regular intervals. The return-wheel at the top of the incline is provided with a powerful brake, which is applied to stop the haulage, should a full tub not be ready to be attached to the rope for each empty tub that is delivered at the top. It is advisable in this, as in all rope-haulages (when it can be done) to have the ropes carried upon the tubs so that they can never touch the floor. Even where this is arranged for, with ropes driven by engines, in the anxiety to get the coals to the pit-bottom, it is difficult to enforce regularity, and thus the ropes trail upon the floor and are rapidly worn out. The regular distances between the tubs on a self-acting gravity-haulage render this impossible; and further, as the ropes are spared the strain to which those actuated by engines and other motors are subject, when tubs get off the rails, the lives of the ropes are very much prolonged. It is found that best plough-steel ropes running close to and on the floor over pulleys at short distances, and more or less wet and dirty, last about 12 months; carried upon the tubs, but frequently touching the floor, about 21 months; and on gravity and haulage-roads when they are carried on the tubs, and never touch the floor being thus kept dry, 5 or 6 years. For those who have to be continually purchasing haulage-ropes, further comment is unnecessary. Where the roofs are bad, it is often arranged that the empty tubs shall enter by one and the full tubs leave by another road. Where it can be done, by far the cheapest haulage of coal has been accomplished by forming the workings into parallelograms, one or more of whose sides represent the working coal-faces, and having the haulage-roads arranged in close proximity. The roads are fitted with a single way, and the empty tubs passing in one direction, are gradually replaced on the rope by full ones, which come out in a different direction. By this arrangement, those who bring the full tubs from the faces attach them to the rope and disengage the empty tubs, so that practically the only cost of the rope-haulage, in addition to the maintenance of the roads, is the price of the ropes and the motive power. By fixing the clip-attachment on the side of the tub at the forward corner, it can be swung round a right angle or quicker bend on a wheel, with a 3 feet radius. It is now the

practice, in all collieries carried on with modern ideas, to have the main-haulage roads laid out on a definite plan. In an unproved coal-field, circumstances often render modifications necessary in such plans, but the ruling ideas are adhered to as much as possible. Haulage-roads are generally driven straight between points.

Owing to the indifferent quality of some of the Scotch coal-seams, which often contain bands of dirt and of coal of varying character, great attention has within recent years been paid to the cleaning and separation of these at the pit-mouth. Much ingenuity has been applied, with a gradual evolution of the best practice during the past twenty years. For large outputs in the latest arrangements, the tubs self-act from controllers on the cages, as soon as these arrive at the top. The full tubs then either gravitate to the weighing-machine, over which they are taken by a creeper and so on to the tipplers; or they are at once taken in charge by a creeper, which moves them up an incline and over the weighing-machine, whence they gravitate to the tipplers. In the former case, after being emptied, the empty tubs are raised up an incline by a creeper, and so gravitate back to the opposite side of the cage to that on which the full tubs leave it. In the latter case, the first creeper referred to, takes the full tubs to an elevation sufficient to enable them, after leaving the tipplers, to perform the journey unaided to the side of the cage for empty tubs. In both cases, the empty tubs are held in position by controllers, and run on to the cage as the full tubs run off. When properly arranged, the whole movement from the cage to the tipplers and then back to the cage is practically automatic; and for this purpose, the gradients on the straight and curved roads are carefully adjusted. The most satisfactory way of arriving at these is to make a thorough test for each plant on trial-roads prior to the permanent ones being laid down, too much speed being almost as bad as too little. The expense of landing or banking a large output is thus reduced to a fraction of what it was, when large numbers of powerful men had to be employed, pulling the tubs out of the cages, and running them to the screens.

The tipplers are power-driven and deliver the coal, which is mixed large and small as it comes from the miner's shovel, backwards on to a curved iron-plate: thence it slides on to a distributing-jigger set at a flat inclination, so as to evenly pass the

coal on to a second jigger, pierced with holes to remove the small coal which falls on to a trough-conveyor underneath, provided with scrapers attached to chains: and these convey the small coal to any desired destination. The large coal passes from the separation-jigger on to a picking-band, composed of bars of iron with interstices between. On this band, as it passes along, all stones and extraneous matter are picked out, and pieces of coal of various qualities removed, the remainder passing on to the end of the band, which radiates from a fixed centre so that it can be lowered or raised as the wagon on the railway is empty or full, thus obviating breakage. Any small coal made by breaking the large pieces on the picking-band to remove dirt, etc., falls through the interstices between the bars to a plate underneath, on which it is scraped back to the small-coal conveyor previously mentioned. The scraper-plates, which are attached to the band, when on its top side are utilized for preventing the large coal on its radiating-end from sliding too rapidly into the wagon. Other arrangements are largely in use: in one of the best of these the coal is tipped on to a slow-motion band, made of overlapping steel-plates; this travels at about 10 feet per minute, and delivers the coal very gradually and evenly upon perforated jiggers which free it of small coal: the large coal then passes very evenly on to a picking-band of similar construction, moving at about 50 feet per minute, where it is freed of dirt, etc., as before described: from this it passes on to a long jigger at a flat inclination, which has perforations to remove any small coal made in the cleaning process, and on this jigger the coal can be finally picked before it is passed into the wagon, breakage being prevented by the hinged-end of the jigger, which can be lowered well into the wagon when empty, and raised as it fills. The stones and rubbish are removed by conveyors placed at right angles and underneath the picking-bands, and from the ends of these they are delivered into wagons or sometimes carried by steep scraping trough-conveyors to a tub on the gangway to a rubbish-heap.

Washing and separating small coal, which passes through holes in the screen-jiggers of about 2 to 2½ inches in diameter, is largely adopted. The general arrangement is to elevate this from a boot, into which it is delivered by the conveyors from the screens, to a circular riddle which separates it into several sizes, namely:- Gum through ¼ inch holes, pearls over ¼ inch and

through ½ inch, singles over ½ inch and through 1 inch, doubles over 1 inch and through 1½ inches, and trebles over 1½ inches up to 2 or 2½ inches, the latter being delivered at the end of the riddle. The gum and pearl coals are washed in felspar-boxes, and the larger sizes in bash-boxes. The washing of the various sizes by themselves is found to effect the removal of the foreign matter most effectually. Greater subdivision in the washing-boxes is sometimes resorted to, the nuts being remixed if necessary, and delivered as trebles, doubles, singles, pearls and gum coals. The extremely fine dust, that is carried with the water, is conducted by it into a tank made of iron-plates, in which works a dredge moving very slowly so as to avoid disturbing the water. Much of the fine-coal mud or sludge soon settles in the bottom of the tank and is scooped up by the dredge and delivered to the boiler stoke-hole. The finer material, which floats longer, remains suspended among the water till the washing is over for the day, and it then settles in the still-tank, from which the water is periodically run off in layers from the top downwards before washing is resumed. All the water used is run into a well, whence it is pumped back to the washery, and thus used over and over again, none escaping except by leakage from the machinery and from the washed coal in the railway-wagons. By this process, it is unnecessary that any dirty water should escape, and thus one of the former great objections to coal-washing has been overcome.

In Scotland, it is the exception to manufacture the small coal into coke, as in most districts the quality of the coal is not suitable. Where it is of the proper quality, however, this is resorted to, and many extensive ranges of beehive coke-ovens are at work. Within recent years, a start has been made with bye-product recovery-plants, the largest of which has 100 Semet-Solvay ovens, which carbonize about 400 tons of coal a day. Besides an enlarged yield of coke as compared with beehive coke-ovens, sulphate of ammonia, benzol, naphtha, creosote-oil and pitch are manufactured. The washed small coal is ground fine and charged from conical bogies into the ovens at their tops. After being converted into coke, the doors of the ovens are opened by an electric crane, and the coke is pushed on to a sloping bench; there it is quenched, and rolls on to a conveyor which carries it to jigging-screens, used to remove the small, and the coke is thus delivered from the ovens automatically into railway-wagons.

The modes of working the coal-seams in Scotland are practically confined to the stoop-and-room, or pillar-and-stall, and long-wall systems. The former is found most advantageous in coal-seams lying at moderate depths, and upwards of 4 feet in thickness; and the latter in thinner seams, and in thick seams at greater depths. At one time, considerable quantities of coal were sacrificed when removing the stoops, but in the best practice for the last quarter of a century, these workings have been carried on in a manner that leaves little to be desired. In the first working, the rooms on stalls are generally driven 10 to 12 feet wide, and the pillars are left so large that not more than 15 to 20 per cent. of the coal is removed. When the boundary or other convenient distance is reached, the pillars are worked back in slices, about 15 feet in width. One great secret of success, in doing this, is to completely timber the excavations. A narrow passage for the road is left near the solid coal of the stoop; the remaining part of the excavation is filled with trees, placed as near one another as they can be inserted. On the completion of the excavation of the slice to the end of the stoop, these trees are drawn and the roof is allowed to subside.

Drawing timber, in such circumstances, is performed for the production of many millions of tons of coal per annum, and an accident is of rare occurrence at what, by limiting the number of trees, was at one time the most dangerous of mining operations. When the roof is bad, it is found better to allow the finished rooms to fall; and, when roads are required for removing the coal in the stoops, to cut these off the stoops along the side of the former excavation. In most cases, roads in such positions stand far better than new ones driven through the centres of the stoops. Workings on this system are equally advantageous whether in the solid or in the broken: in the former (that is, in forming the rooms) the miner is paid a higher rate per ton, but the coal produced is better and contains less small; and, in the latter, the rate is less, but the coal is more crushed and much timber is used.

Longwall workings are generally conducted with faces, 36 to 45 feet in length, with a road in the centre. These roads are formed by the roof being ripped or brushed, and are maintained by having strong buildings inserted between the floor and roof, parallel to their lengths. The main roads subside after a time,

and have to be heightened, while the branch-roads are cut off by new slopes and abandoned. These roads are an expense incident to the longwall system and this cost is avoided in the stoop-and-room system formerly described.

The circumstances of seams in various localities lead to modifications in the systems of working which are of interest. Where two or more seams occur near to one another, they are successively worked by the longwall system. The bottom seam is taken first, followed by the seam above, and in many cases the same drawing-roads serve both workings. The rubbish used to stow the workings of the bottom seam is made the holing for that above, and is thus only turned over. The top seam settles down on this rubbish, and is begun to be removed from that point. When a third seam is present, it is usually worked backwards, after the other two are exhausted. To render such a working successful the chief consideration is that the rubbish, available for stowing the excavation of the bottom seam first worked, should be sufficient. In five collieries where the bottom seams range from 4½ feet to 6½ feet in thickness, and the top seam from 3½ feet to 4¼ feet in thickness, the rubbish available for stowing ranged from 30 to 40 per cent. of the excavation. It is found that the former has to be augmented, and, after careful consideration of the subject, the conclusion may be accepted that to make a good working of two seams in close proximity to one another, the strata available to stow the initial working should be equal to 40 per cent. of the excavation.

In his able address to the members, delivered in Glasgow, in September, 1901, Sir W. T. Lewis dwelt at length on the question of loss of coal in working.* This is a matter that has received a good deal of attention in Scotland. Since the advent of washing, it is rare that small coal is left underground, and both the lessees and lessors of collieries are alive to the necessity of allowing no unnecessary waste. In a recent paper read before the members of the Mining Institute of Scotland, Mr. James Barrowman considered the subject of "What is the least possible Waste in working Coal?"† He compared the actual production with that calculated as contained in certain areas mined over in seams of various thicknesses and differently situated, and worked both

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 280.

† *Ibid.*, 1902, vol. xxiii., page 55.

by the stoop-and-room and longwall systems. In a total quantity of 37,507,956 tons he found that the average loss was only 2½ per cent., that for stoop-and-room being 3·77 and that for longwall only 0·11 per cent. For my own information, I have from time to time made investigations similar to those conducted in a wider sphere by Mr. Barrowman, and these give similar results. In one case, with three-fourths of the workings on the stoop-and-room system in four seams, 3¾ feet to 7 feet thick, with good and bad roofs, the results were by calculation 4,910,122 tons and by output 4,895,378 tons or a loss of 0·3 per cent. In another case, where the workings were nearly all stoop-and-room, chiefly in one seam 6 to 7 feet thick, the results were by calculation 2,899,446 tons and by output 2,966,266 tons or a gain of 2¼ per cent. In another colliery, where the workings of five seams from 2 feet to 4 feet thick are entirely on the longwall system, the results were by calculation 2,875,487 tons and by output 2,910,173 tons, showing a gain of fully 1 per cent. From these figures, the conclusion can be drawn that in well-managed workings on the stoop-and-room system, the actual loss in working is reduced to a very low percentage, and in longwall practically the whole of the coal contained in the excavated areas is produced.

In this relation, much coal that was formerly considered as lost, or as rendered unworkable, is now being recovered. In one seam, 7 feet to 8 feet thick, the upper part of the coal was inferior in quality with a bad roof above; 2 feet to 3 feet of coal was left unworked, and the remainder removed by the stoop-and-room system: the method of extracting the stoops was at the time not very complete, many corners being left. By the crushing of these, the head coal was allowed to settle down, without being severely broken up. The seam for many years was looked upon as exhausted, but, as other coal became scarce, attempts were made to work it, and this has been done successfully, both the small stoops and the head coal being got. In another instance, two seams of coal, the top one being 3½ feet, and the bottom one 2 feet, thick, were separated by 6 inches of shale, the top portion was a first-class splint coal and being in much request for the ironworks was worked out by longwall upwards of 30 years ago. Coal becoming scarce, an attempt was recently made to work the 2 feet of coal under the old stowage. This was found to have been consolidated, so as to be almost as consistent as many an inferior

roof; and the 2 feet of coal is now being successfully worked, the roadways being ripped through the old stowage, which is now consolidated to about 2 feet in thickness. The trees used in the upper working are often found, having been squeezed downward through the intervening 6 inches of shale. These instances go to show that, so long as seams of coal remain intact and are not actually broken to pieces by the working of other seams, they cannot be considered as lost.

Coal-working by machinery is making considerable progress in Scotland. According to H.M. inspectors of mines there were 49 machines at work during last year, which produced 485,584 tons. All these, except two, are disc-machines used for undercutting in longwall workings. At Sanquhar colliery, there are two Jeffrey stoop-and-room machines at work, one being electrically and the other pneumatically driven. The electric machine, which weighs 30 cwts., is attended by three men; when cutting in coal it absorbs 15 horsepower, the width of the cut is 3 feet 8 inches, and it penetrates to a depth of 6 feet, the incision being 4 inches high. It takes four cuts to complete the width of a room 14 feet wide, and this is done in about 1 hour. The machine is then drawn on to a bogie, and thus transported to the next room to be undercut. Disc-machines in longwall are driven both by air and electricity, the latter is becoming more general. Coal-cutting by machinery is found of greatest advantage in seams of about 2 feet in thickness with good roofs; and in districts where such seams are largely worked, the employment of coal-cutters is fast becoming general. With the object of rapidly opening out coal-workings, Stanley heading-machines have been usefully employed. Under my own supervision, many miles of places, 11 feet in width, were driven by these machines, and they did the work at four times the speed of manual labour, but at twice the cost.

For all purposes where it is necessary to transmit power, electricity is rapidly coming into general use. All important collieries have installations in use for one purpose or another. Pumps are numerous, forcing as much as 500 gallons per minute against heads up to 600 feet: these are generally of the three-throw type, and are doing good work. Electric hauling is becoming almost universal, conducted principally on the endless-rope, and also on the single-rope and main-and-tail-rope systems.

Lighting by electricity is general, and usually embraces the surface-works and shaft-bottoms, and in some instances the workmen's cottages.

A subject of the first importance, both from national and personal points of view, is that of saving in the consumption of fuel: it being well known that collieries are extremely wasteful in that respect. This has been fostered by the worthlessness of fuel at the pit-mouth, where the inferior qualities are generally consumed. But in these days of improving these qualities and the cost of firing, removing ashes and providing expensive boilers, there is now sufficient inducement to adopt better means of raising and employing steam economically. This is being met to some extent by improved boilers of water-tube or Lancashire types, and high-pressure steam, at 80 to 100 pounds per square inch and in some cases even more, are now becoming general, with compound-engines, especially used for pumping, driving electric engines, fans, etc. In collieries spread all over Lanarkshire and embracing every circumstance of working, so that they may be taken as a fair average of the country in general, of an output of 10,380,182 tons 767,324 tons or 7·39 per cent. was consumed at the collieries. On the output of the United Kingdom for last year at the above rate, the fuel consumed at the collieries would amount to 16,186,852 tons.

Not being aware of any trials of the actual consumption of fuel by ordinary colliery-engines, I had a careful test made at a colliery at which 15 engines are employed. These comprised the following engines:—A compound-condensing for pumping and a compound-condensing for electric machinery; and the following high-pressure engines, two for winding, one for electric lighting, one for fan, two for screens, two for air-compressors, two for haulage, two feed-pumps for boilers, and one each for workshops, hoist and steam-hammer. When all were at work, the indicated horsepower amounted to 1,202, but many of these engines worked very intermittently, so that the whole indicated horsepower developed in a cycle of 24 hours was 10,915. There were four Lancashire boilers, 30 feet long by 8 feet in diameter; and six Babcock and Wilcox water-tube boilers. The steam-pressure was 75 to 80 pounds per square inch during the test. The temperature of the feed-water varied from 122° to 150° Fahr. The fuel was small coal, which passed through circular holes 2 inches

in diameter; the ash-residue amounted to 11·6 per cent., and 6·55 pounds of water were evaporated in the boilers per pound of fuel consumed. The total water evaporated in a cycle of 24 hours was 587,284 pounds, which gives 53·8 pounds of water per indicated horsepower per hour, and 8·21 pounds of fuel were consumed per indicated horsepower per hour. The indicator-diagrams were carefully taken, and it was calculated from these that the actual steam accounted for in the cylinders amounted to 484,407 pounds in a cycle of 24 hours, and that 6·76 pounds of fuel were consumed per indicated horsepower per hour, thus showing a loss of 17½ per cent. by condensation in long lengths of steam-pipes, and in engine-cylinders, leaking joints, steam blowing off at safety-valves, etc. The total quantity of coal consumed, divided by the total indicated horsepower in a cycle of 24 hours, gave the same result of 8·21 pounds per indicated horsepower per hour. The results from the different engines are instructive, the high-pressure winding-engines taking 9·87 pounds of fuel per indicated horsepower per hour as compared with 3·34 pounds used by the compound-condensing engines driving the electric dynamo. As is well known, in the best marine practice an indicated horsepower per hour is got from 1½ pounds of fuel; and a well known authority on gas-engines had lately said that with producer-gas 1 pound of fuel would give an indicated horsepower per hour with the best types of that class of motors. High-class steam-coal is used in marine practice, while at collieries the worst fuel is generally utilized for that purpose. Taking this fact into consideration, in conjunction with the tests already mentioned where the fuel was of fairly good quality, the generally accepted idea that at collieries at least 10 pounds of fuel are consumed per indicated horsepower per hour seems very near the truth. As was proved by the tests, the compound-condensing engine was using only one-third of the usually accepted quantity of fuel, so that by this means alone a very large saving can be effected.

At an up-to-date colliery of the future, I anticipate that winding, pumping and other operations will be carried on by electricity generated at a central station by a duplicate set of compound or triple-expansion condensing engines or turbines, with superheated steam at a pressure of 150 or 180 pounds per square inch. The engines being thus located at one spot can be placed in close

proximity to the boilers, thus avoiding the use of long lengths of steam-pipes and numerous steam-cylinders, all of which conduce to condensation and loss.

By the application of central steam-condensers, with towers for cooling and condensing the heated water if necessary, high-pressure steam and improved engines, I imagine that the 10 or more pounds of fuel per indicated horsepower per hour, now consumed at collieries, could easily be reduced by one half thus effecting a saving throughout the kingdom of upwards of 8,000,000 tons of fuel per annum, and with a central electric or gas installation, as referred to, the saving might be 10,000,000 tons a year. I submit that this is worth careful consideration by those interested.

In this address, I have given a rapid and rather cursory review of some of the features of mining as carried on in those districts of Scotland of which I have most knowledge, together with a few subsidiary remarks on cognate subjects, all of which I trust may be of some interest to the members of The Institution of Mining Engineers.

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Sir Lindsay Wood, Bart. (Chester-le-Street), in moving a vote of thanks to the President, said that the address entered in such detail into the nature of the coal-seams of the Scotch mines and the methods of working them that it would constitute a most valuable source of reference.

Mr. James Stirling (Victoria), in seconding the vote of thanks, said that he had recently had the opportunity of visiting some of the principal coal-fields of Europe, notably of Germany and Austria, and, while there was probably something to be learned from the methods applied there, especially the electrical methods, and from their ways of dealing with their workmen (which might well be copied here) it was evident that most of the improvements in mining engineering were being exemplified in Scotland.

Mr. J. S. Jeans (London), in supporting the motion, said that it was gratifying to learn that the mining of coal by machinery was making notable progress in Scotland, and throughout this country.

Mr. Emerson Bainbridge (Sheffield), in supporting the motion, asked Mr. Dixon whether in Scotland there was any central condensing-plant or electric plant such as was mentioned in the address; and it would be interesting, to some of the members who were trying to arrange similar plant, to know whether Scotland was the pioneer in this respect.

The vote of thanks was cordially adopted.

The President, in acknowledging the compliment, hoped that while there was perhaps nothing very new in the address, it might prove useful to some of the members. With reference to the question of a central condensing-plant, he contemplated erecting one himself, as the figures submitted clearly showed the advantage of such an installation.

Prof. C. R. Van Hise and Mr. H. Foster Bain's paper on "Lead- and Zinc-deposits of the Mississippi Valley, U.S.A.," was read as follows:—

# LEAD- AND ZINC-DEPOSITS OF THE MISSISSIPPI VALLEY, U.S.A.*

By C. R. VAN HISE and H. FOSTER BAIN.

## I.—Introduction.

The mines of Wisconsin, Illinois and Iowa will be called the upper mines, and the district in which they occur the upper district; while the mines of Missouri and Arkansas will be called the lower mines, and the districts in which they occur the lower districts.

The lead- and zinc-deposits of the Mississippi valley are among the largest deposits of these minerals yet exploited. In 1900, the production of these mines had an aggregate value of more than £3,000,000 (15,000,000 dollars). It is impossible to give exact figures for the entire output, but some idea of its importance may be gathered from the fact that the Joplin district alone produced 484,660,410 pounds of zinc-ore and 59,013,390 pounds of lead-ore, the two having a value of £1,595,460 (7,977,304 dollars) at the point of production. In the same year, the lead-mines of Southeastern Missouri produced approximately 75,000,000 pounds of pig-lead, and there was a small production of both lead and zinc in Iowa, Wisconsin, Illinois, Kentucky and Arkansas. The zinc-smelters of Missouri, Kansas, Illinois and Indiana made 114,972 short tons of spelter, and a conservative estimate of the total pig-lead produced in this region is 51,900 short tons. In addition to the spelter, a considerable amount of zinc oxide was burned, but the ore used in this business may be off-set by that obtained from Colorado and other western states, and made into spelter at works in Illinois and Indiana. In 1900, very little ore was exported from this region, but in 1901 zinc-ores were shipped from Joplin to foreign smelters *via* the Gulf ports. The zinc-mines of the Mississippi valley now furnish 90 per cent. of the zinc-output of the

* Published by permission of the Director of the U.S. Geological Survey.

United States, or 20 per cent. of the world's production. The lead-region of South-eastern Missouri produces approximately 22 per cent. of the output of the United States, or 7 per cent. of that of the world. If the lead-output of the Joplin region and that of the upper Mississippi mines be added, these figures would be considerably increased. In addition to lead and zinc, the mines of South-eastern Missouri produce an important portion of the American output of barytes, and the mines of Southern Illinois and the adjacent portion of Kentucky yield the bulk of the fluor-spar mined in the United States.

## II.—Historical Summary.

Mining in the Mississippi valley dates back to the earliest period of its exploration and settlement by whites. Indeed it was the hope of mineral wealth which attracted the first Spanish and French explorers to the region, and the finding of lead brought about the first attempt at regular settlement. Le Sueur, in 1700 or possibly earlier, first noted the presence of lead in the valley. The first attempt to work the mines was made in Missouri in 1720 when the "Company of the West," organized in France by John Law, sent out Renault and La Motte, who began mining in the Ozarks. The famous La Motte mine was opened at that time, and has been worked more or less constantly ever since. The upper mines were not worked until a half-century later. From 1788 to 1810, they were actively operated by Julien Dubuque. In the earlier half of the nineteenth century, the upper mines were by far the more productive and important, but for some years the lower mines have been much the heavier producers.

In the course of the development of the region, it has been studied by the principal American and foreign geologists and mining-engineers, and much that is interesting relating to ore-deposits has been learned. The history of these investigations will be found in reports on Wisconsin,* on Iowa,† and on Missouri.‡ The ore-deposits of the valley are very exceptional in that they are in a region almost entirely free from intrusions of igneous

* "The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin. *Geology of Wisconsin*, 1882, vol. iv., pages 365 to 571.

† "Geology of Dubuque County," by Messrs. Samuel Calvin and H. F. Bain, *Iowa Geological Survey, Annual Report for 1899*, 1900, vol. x., pages 379 to 651.

‡ "Lead- and Zinc-deposits," by Mr. Arthur Winslow, *Missouri Geological Survey*, 1894, vols. vi. and vii.

rocks and in rocks which have not been subjected to severe orogenic forces. It is a great area of generally little disturbed sedimentary rocks, mainly of Palæozoic age.

The present paper is concerned with certain general problems of the region relating particularly to the genesis of the ores and the principles which controlled their deposition. It is believed that these principles have wide application not only to lead- and zinc-ore but to ore-deposits in general, and that a brief general statement of them and the evidence for their application in this region will be of benefit elsewhere. The main outlines of the theory of genesis herein discussed were developed by the senior author of this paper in the course of his studies for the United States Geological Survey. In 1899, after a brief study of the Wisconsin lead- and zinc-mines, the principles were found to apply to the upper mines. A general statement of the whole case was made in a paper read before the Washington meeting of the American Institute of Mining Engineers.* The first application of these principles to lead- and zinc-ores was made in the Iowa-Wisconsin district, and a historical statement would naturally require that that district be first treated. It is in many ways advantageous, however, to describe first the districts of the Ozarks, since in certain particulars the application of the theory is much more certain there than in the district to which it was first applied. The Missouri-Kansas or South-western Missouri district has been studied in considerable detail by the junior author under the direction of the senior author.† Its greater economic importance makes it better known, and this is another reason for devoting the major part of a necessarily short paper to it.

## III.—Regions and Districts recognized.

The lead- and zinc-mines of the Mississippi valley may be divided into three divisions: (1) those of the Ozark region; (2) those of the Upper Mississippi valley region; and (3) those of outlying districts. Of these, the first, that of the Ozark region, is

* "Some Principles controlling the Deposition of Ores," by Mr. C. R. Van Hise, *Transactions of the American Institute of Mining Engineers*, 1901, vol. xxx., pages 27 to 177.

† "Preliminary Report on the Lead- and Zinc-deposits of the Ozark Region," by Mr. H. F. Bain; with an "Introduction," by Prof. C. R. van Hise; and chapters on the "Physiography and Geology," by Mr. George I. Adams, *Twenty-second Annual Report of the United States Geological Survey*, part ii., pages 23 to 227, 38 figures, and plates VI. to XXV., and pocket-map.

by far of the greatest importance, and includes four districts, namely, the Missouri-Kansas district, the South-eastern Missouri district, the Central Missouri district, and the North Arkansas district. The Upper Mississippi valley includes a single district, that of Wisconsin, Iowa and Illinois. The outlying districts are two in number; namely, that of Southern Arkansas, and that of Illinois and Kentucky. Therefore there are in the Mississippi valley seven districts which will be treated in order, as follows: —

1. The Missouri-Kansas district of which Joplin in Missouri, and Galena in Kansas are the best-known towns. This is essentially a zinc-producing district, though an important amount of lead-ore is also mined. It is characterized by great irregular runs of rich ore.

2. The South-eastern Missouri district, essentially lead-producing and largely known because of its disseminated ores and the large mining and milling operations, which that form of deposit has made possible. The La Motte, Bonne Terre, Doe Run and Flat River mines are typical.

3. The Central Missouri district, an area of indefinite outline not yet fully prospected, and characterized so far as yet developed by small ore-bodies of both lead and zinc.

4. The North Arkansas district, an extensive area, as yet only partially prospected and almost wholly undeveloped, but showing a wide variety of rich zinc-ores and some very promising prospects. Yellville is perhaps the best known town in the district.

5. The Wisconsin-Iowa-Illinois district was an early and important producer of lead; but during its middle and later history, nearly up to the present time, it has principally produced carbonate-of-zinc-ores. Sulphide ore-bodies occur in the district, and are now being marketed to a notable extent. Mineral Point, Platteville and Highland, Wisconsin; Dubuque, Iowa; and Galena, Illinois, are important centres of production.

6. The South Arkansas district, comprising a part of the Ouachita mountains, in which zinc and lead occur in fissure-veins accompanied by small amounts of gold and silver. In character and genesis, the ores of this area seem to vary notably from those of the districts previously enumerated. They have not yet been studied in detail, and are not especially considered in this paper.

7. The Illinois-Kentucky district, characterized by the presence of both lead and zinc, accompanied by notable amounts of

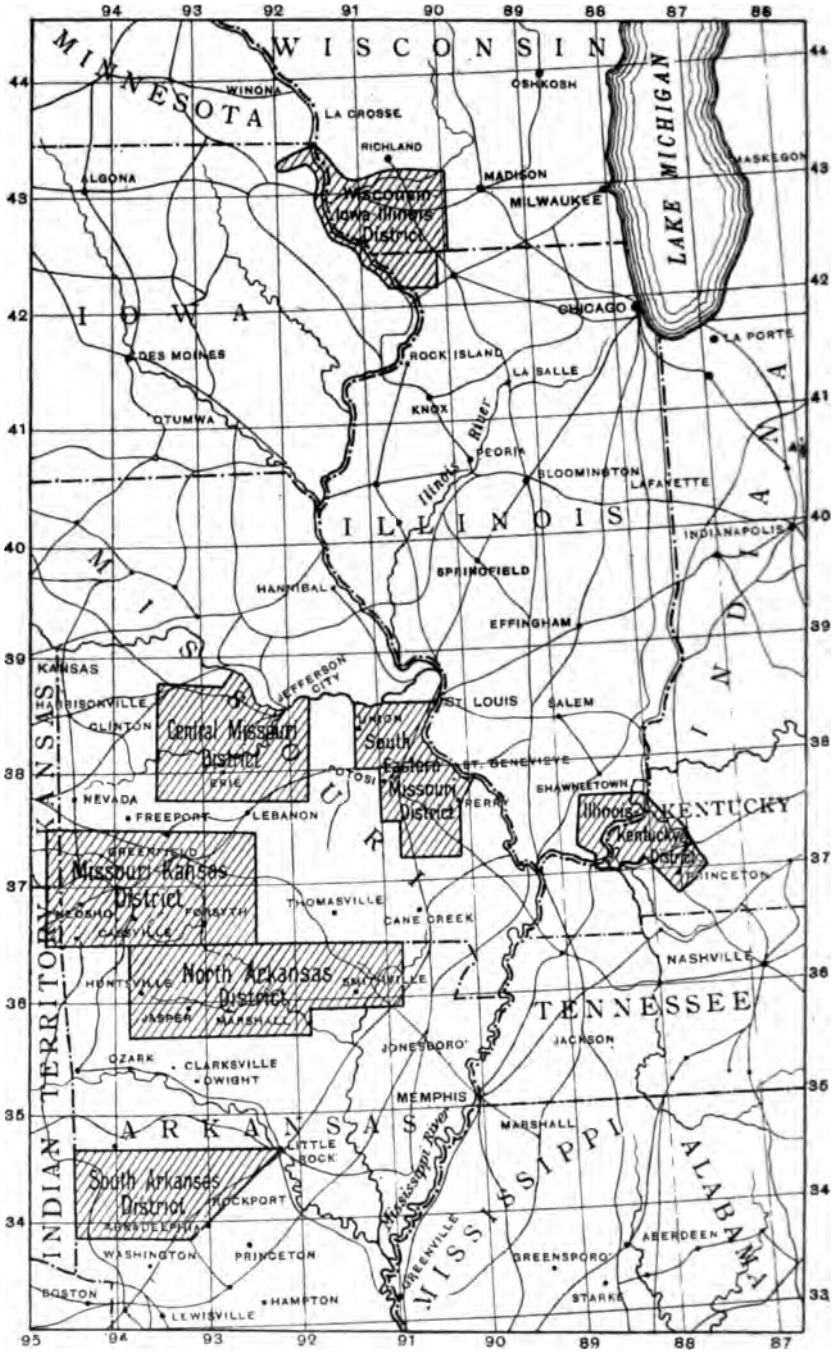


FIG. 1. -MAP OF THE LEAD- AND ZINC-DISTRICTS OF THE MISSISSIPPI VALLEY, FROM OFFICIAL SURVEYS, 1901. SCALE, ABOUT 120 MILES TO 1 INCH.

fluorspar, an association unique so far as the ores of the Mississippi valley are concerned, but linking them in character with the ores of the North of England.

The general geography of the valley and the location of the various districts are shown on the accompanying map (Fig. 1).

## IV.—The Ozark Region.

### A. *General Description.*

The Ozark region is a roughly elliptical area, approximately 300 miles in length from north-east to south-west and 200 miles in breadth. It embraces the southern half of Missouri, the northern third of Arkansas, and small adjacent portions of Illinois, Kansas and Indian Territory. In general structure it is a low, shield-shaped dome bevelled by erosion, with the oldest strata exposed a little north-east of the centre, and the younger beds concentrically disposed about this core of older rocks. This general structure is well shown in Fig. 2, a generalized cross-section from west to east. In Fig. 3, a generalized section from north to south is represented; but the section being taken somewhat west of the structural centre of the uplift, the oldest rocks are not shown. The rocks which are exposed in the region in order of age are as follows:—

1.—*Pre-Cambrian.* The pre-Cambrian is a group of crystalline rocks, mainly granites and porphyries, but with minor masses of basic dykes. These rocks form the core of the St. Francis mountains. Similar rocks have been encountered in other parts of the region in deep drill-holes, and on the western flank of the uplift there are small outcrops of rock presumably belonging to this group. The pre-Cambrian forms the base or floor upon which the sedimentary rocks were laid down.

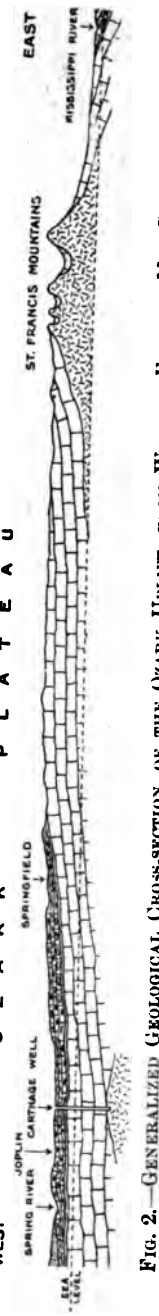


Fig. 2.—Generalized Geological Cross-section of the Ozark Uplift, from West to East, by Mr. George I. Adams.

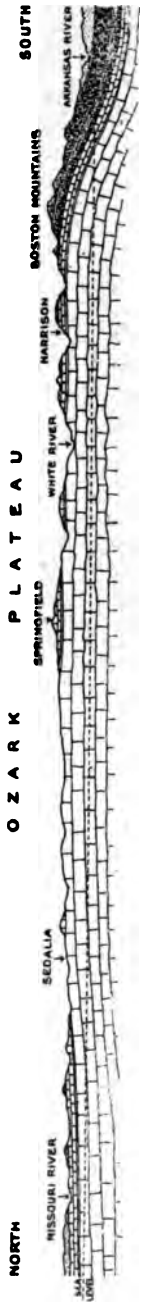


FIG. 3.—GENERALIZED GEOLOGICAL CROSS-SECTION OF THE OZARK UPLIFT, FROM NORTH TO SOUTH, BY MR. GEORGE I. ADAMS.

2.—*Cambro-Silurian.* The lowest series of sediments are Cambro-Silurian magnesian limestones, dolomites and sandstones. The exact sequence has not been worked out, except in certain small areas; and for the present purpose it is necessary to treat the series as a unit. It has a general thickness varying from 1,500 to 2,000 feet.

3.—*Devonian.* Strata belonging to the Devonian system have been recognized only along the north-eastern border of the uplift. A predominantly shaly bed showing affinities to both the Devonian and the Lower Carboniferous is found, however, almost entirely around the uplift. This shale, for convenience called the Eureka-Kinderhook, while thin, is of great significance in its relations to the ore-deposits.

4.—*Lower Carboniferous.* The Lower Carboniferous is represented by an important series of non-magnesian limestones, which contain the ore-bodies, and attains a thickness of approximately 400 feet in the Missouri-Kansas district.

5.—*Upper Carboniferous.* Above the Lower Carboniferous limestones and fringing the uplift (except to the south-east where a recent fault brings the Tertiary into juxtaposition with the Cambro-Silurian) is a thick series of shales and sandstones belonging to the Coal-measures of the Upper Carboniferous.

The Cambro-Silurian rests in marked unconformity upon the pre-Cambrian. The Eureka-Kinderhook shale is in turn unconformable with the Cambro-Silurian, although in this case the plane of unconformability is a remarkably even plane. The Lower Carboniferous limestones are conformable among themselves and with the Eureka-Kinderhook shale. The Upper Carboniferous lies in marked unconformity upon the Lower Carboniferous limestones. The limestone-surface, upon which the

shales were laid down, had evidently been subjected to vigorous erosion, and was cut with deep channels and basins at the time when the shales and sandstones began to be deposited over it.

The general lithologic sequence present in the Ozark region from the top downward is as follows:—

1. Thick shale and sandstone.
2. Non-magnesian limestone and chert.
3. Shale, thin.
4. Magnesian limestones, dolomites and sandstones.
5. Crystalline rocks.

It is probable that, at one time, the younger rocks completely covered the older, but as a result of erosion they now crop out in fringing-belts around the central core of older rocks.

The structure of the uplift seems to be due to relatively recent earth-movements, possibly going as far back as the Cretaceous, but occurring probably chiefly in the Tertiary. The exact character of these movements has not been worked out, but the result has been the production of slight quaquaversal dips of 10 to 20 feet to the mile, which seem most pronounced around the edge of the uplift. Widespread but slight faulting and considerable brecciation is present, and seems to have accompanied the uplift.

### B. *Missouri-Kansas District.*

#### 1. Stratigraphy.

The Missouri-Kansas district is located on the western flank of the Ozark uplift. It is a large district, although the principal mines are located in certain circumscribed sub-districts with, as usual, relatively broad and barren areas between them. The entire series of rocks, already enumerated, crop out within the district, but the ore-bodies are in the main confined to the Lower Carboniferous limestone. This limestone is coarsely crystalline and non-magnesian; and it carries an abundant fauna related to the Burlington and Keokuk faunas of the Lower Carboniferous series. While the limestone is almost holocrystalline, the perfection of the fossils indicate that it has been metamorphosed through the agency of circulating waters without mashing. In this and all essential particulars of character and composition, the limestone is closely similar to the Lower Carboniferous limestone developed elsewhere in the Mississippi valley, entirely outside

of the ore-bearing districts. It is impossible to escape the conviction that the ores associated with these beds are secondary. It is also clear that there was a widespread and presumably long-continued circulation of underground waters in the limestone, not only where ores occur, but throughout the Mississippi valley. Associated with the limestone and interbedded with it are considerable bodies of white chert. Whether this chert be primary or secondary as regards the limestone is not altogether clear. In part, it is a replacement of the limestone, and it is not impossible that in the main it is of this nature. But macroscopic and microscopic studies indicate that the white chert is older than the ores, because in no case has any ore been found entirely surrounded by the chert. The ores and the chert are very closely associated, but in every case observed the association is secondary: the ore occupying cracks and fissures in the chert, or forming a matrix around chert-fragments, where the chert has been crushed.

An important fact in connection with the genesis of the ores is the association of asphalt with the limestone. This is not altogether unknown elsewhere in the Mississippi valley, geodes in the Keokuk limestone at Keokuk, having been found full of this material. However, in the vicinity of Joplin and other producing sub-districts, the quantity of asphalt is rather unusual. At the Kingfisher mine, in Chitwood Hollow, the amount is so great as seriously to interfere with the cleaning of the ore, the crushed material coming from the rolls consisting of white chips of chert or limestone with a dark matrix of asphalt, resembling a mastic prepared for street-paving.

As is well known, limestones are relatively soluble by ordinary underground waters. In the district under discussion, large caves and minor open cavities are not infrequent. In places where the calcium carbonate has been entirely dissolved, it is usual to find a dark insoluble residue which contains important amounts of organic matter. The limestone is evidently rather heavily charged with organic matter. Presumably underground waters passing through the limestone for considerable distances would become a reducing chemical agent.

Above the Lower Carboniferous limestone are scattered patches of dark bituminous shale and, occasionally, bodies of sandstone, which represent erosion-remnants of the Coal-measures that formerly covered the entire district. In part these remnants

occupy pre-Coal-measure erosion-basins and have as a result been protected from erosion. In part, they represent blocks faulted down into the underlying beds.

Below the Lower Carboniferous limestone is the Eureka-Kinderhook shale. In the Ozark region, in general, this formation is a shale. In the south-western districts, it is a rather shaly limestone, and as such has heretofore largely escaped notice in such drill-holes as have penetrated it. The formation, normally, 50 to 75 feet thick, is heavily charged with organic matter, and is so firm and close as to constitute, except when broken by fault-

FIG. 4.—FAULT IN THE SLAIGHT MINE, WEBB CITY, MISSOURI.

planes, an impervious barrier separating the waters circulating in the Lower Carboniferous limestones from those circulating in the Cambro-Silurian.

The Cambro-Silurian rocks are principally known in the district through drill-holes or records. They form a great series of rocks of very uniform character, underlying at considerable depths the entire district. Since the dip of the rocks from the centre of the Ozark uplift is greater than the slope of the surface, their area of outcrop to the east is considerably higher than the surface of the ore-bearing district. Indeed the open plain, upon which

Joplin, Galena, Webb City, Cartersville, Aurora and other mining camps are situated, lies some 600 to 700 feet below the outcrop of the Cambro-Silurian beds; although in these camps the Cambro-Silurian is at considerable depths. As a result, surface-waters falling on the area of outcrop and sinking into the Cambro-Silurian strata find their way down along the dip, under the impervious Eureka-Kinderhook shale. In the mining district, this water is under a considerable hydrostatic head and it rises to the surface whenever there is an opportunity. As a result, artesian wells are not unknown, and in the deeper mines there is a steady upward flow of water, which bears no relation whatever to local rainfall or seasonal changes.

FIG. 5.—CHARACTERISTIC BRECCIA OF THE SOUTH-WESTERN DISTRICT, FROM JOPLIN, MISSOURI.

The opportunity for the water of this deep circulation to ascend to the Carboniferous Limestones and through them to the surface, is afforded by numerous faults which break through the intervening shales. These faults, where observed, are rarely single sharp fault-planes, but are a series of fracture-planes or zones of fracture. They are usually accompanied, in the Carboniferous Limestone, by brecciation and clear evidence of extensive solution and deposition by underground waters. Such faults have been

directly observed among other places in the Slaight (Fig. 4), and other mines of the Missouri Zinc-fields at Cartersville, Missouri, in the Circle mines at Oronogo, in the Boston-Aurora, the Sand Ridge and other mines at Aurora, and in numerous mines on the Continental Tract at Joplin. One of these faults has been studied and traced in the Fields down into the Cambro-Silurian on Pierson Creek in Missouri, by Prof. Shepard,* and many others are known to occur.

FIG. 6.—CHARACTERISTIC BRECCIA OF THE SOUTH-WESTERN DISTRICT, FROM PEORIA, INDIAN TERRITORY.

The manner by which the character of the displacement is affected by the nature of the country-rock in this district is both interesting and instructive. The Cambro-Silurian rocks are thickly bedded, homogeneous dolomites. Stresses generated in them or transferred to them accumulate, and are eventually relieved by extensive, clean-cut fractures. The Eureka-Kinderhook, being a shale, yields normally by flexure rather than by fracture, and the same is true of the overlying shales of the Coal-measures. Where the shale is thin or, as is true of the Eureka-

* "Geology of Greene County," by Prof. E. M. Shepard, *Missouri Geological Survey*, 1888, vol. xii., part 1, pages 174 *et seq.*: and for additional details, see "Lead and Zinc-deposits of the Ozark region," *Twenty-second Annual Report of the United States Geological Survey*, part ii., pages 168 to 173.

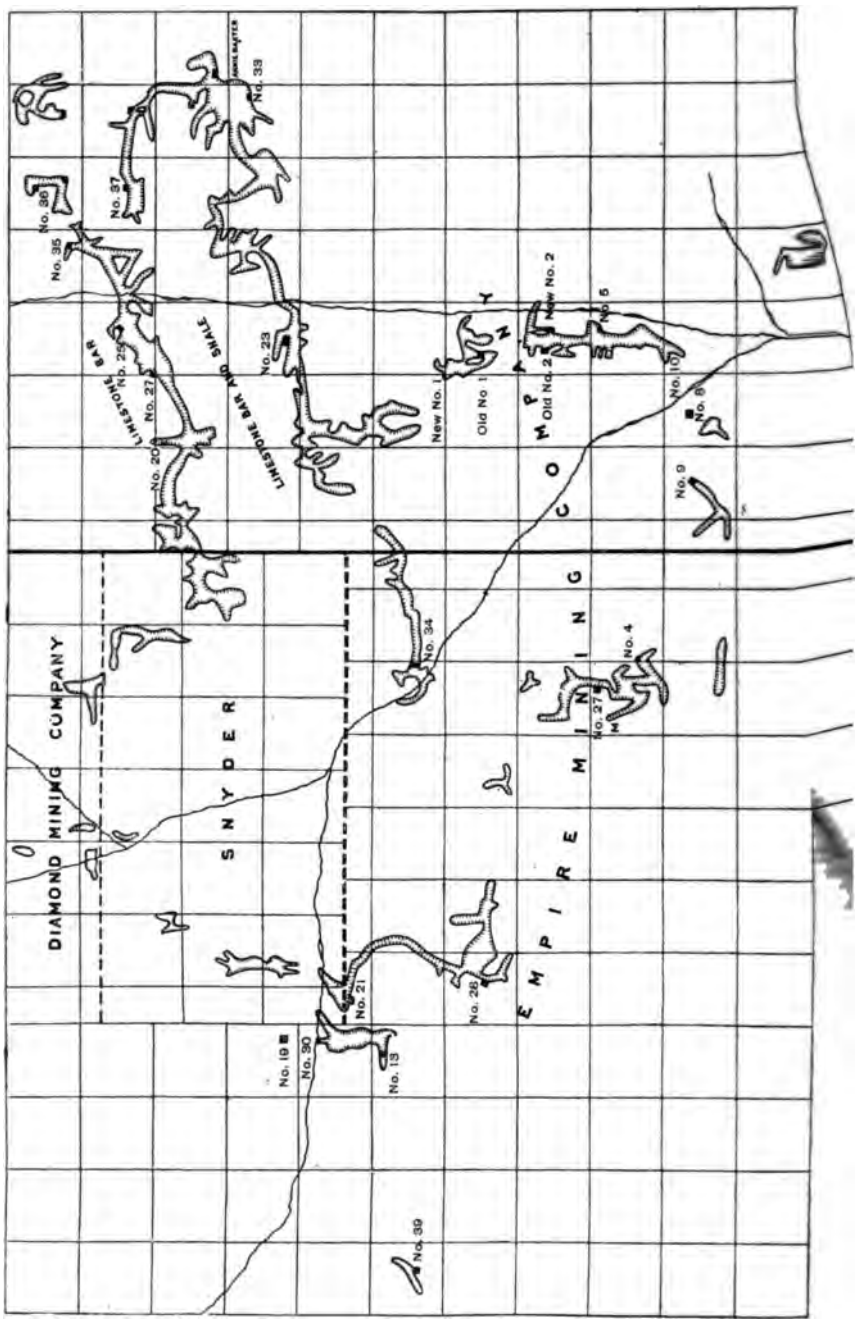


FIG. 7.—GROUND-PLAN OF THE MINES OF THE EMPIRE TRACT, NEAR JOPLIN, MISSOURI. SCALE, 530 FEET TO 1 INCH.

Kinderhook in this district, so calcareous as to be a brittle, shaly limestone, the stresses have also produced fractures. The Lower Carboniferous Limestone is more thinly bedded than the Cambro-Silurian limestone and is much less homogeneous. As a result, deformation is normally accomplished in them by means of many minor fractures. The chert, which accompanies the limestone, is exceedingly brittle and is fractured and brecciated by relatively weak stresses. The limestone being soluble is easily and quickly removed from a brecciated mass of limestone and chert, leaving the small, sharp-angled bits of chert to be re-cemented by material brought in by the solutions. Breccias of this kind are illustrated in Figs. 5 and 6.

The exceedingly irregular outline of the ore-bodies, illustrated in the ground-plan (Fig. 7), is the result of deformation followed by solution and deposition in interbedded brittle chert and soft soluble limestone. It will be noted that while in detail the ore-bodies, as shown by the workings, are exceedingly irregular, in general they are arranged along certain rude lines, which represent the zones of fracture in the limestone and chert. The relations of the ore-bodies to fault-blocks is also shown in the ground-plan of the Oronogo Circle mines (Fig. 8). The same stresses, which in the Carboniferous Limestone produced an irregular breccia, in the more homogeneous Cambro-Silurian limestones probably produced a simple regular fracture-plane, such as commonly gives form to the ore-bodies occurring in the Cambro-Silurian elsewhere in the Ozark region. The stresses acting on the Eureka-Kinderhook shale would probably have been relieved entirely by flexure, if it were not for the calcareous, brittle nature of these beds within the mining district.

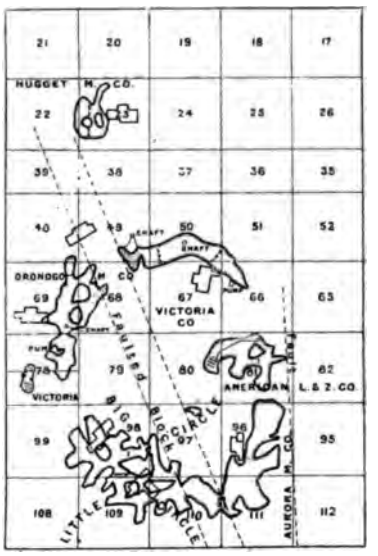


FIG. 8.—GROUND-PLAN OF THE MINES OF THE ORONOGO CIRCLE, ORONOGO, MISSOURI. SCALE, 530 FEET TO 1 INCH.

Certain of the fracture-planes are marked by faulting and the measured throw, 100 to 175 feet, makes it clear that these faults

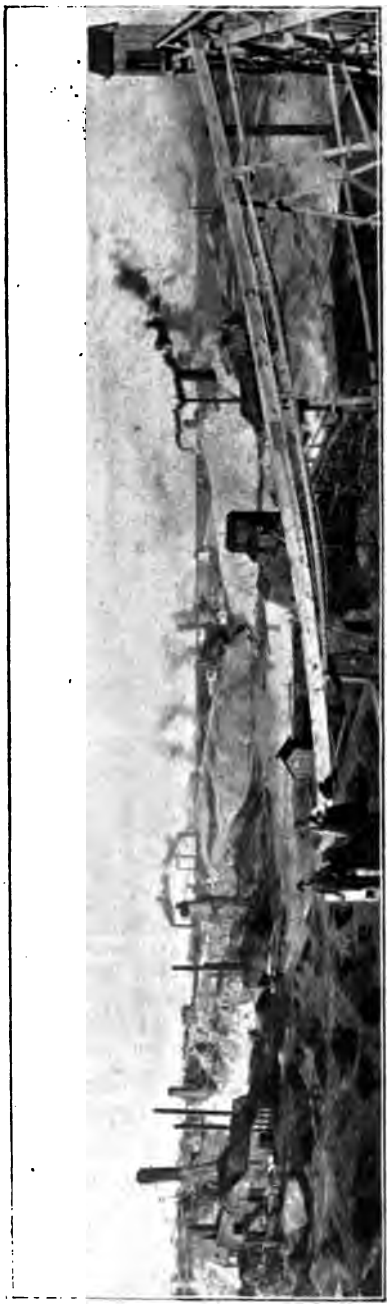

FIG. 9.—ZINC-MINES NEAR WEBB CITY, MISSOURI, ILLUSTRATING THE USUAL STYLE OF PLANT AND THE LARGE NUMBER OF MINES IN A GIVEN AREA.

extend down into the Cambro - Silurian. The fault-planes thus afford opportunities for artesian waters, within the Cambro-Silurian, to rise into the irregular brecciated belts of the Lower Carboniferous.

2. Ores and Ore-bodies.

The ores of the district are those of lead and zinc, and both occur predominantly in the sulphide form. Minor amounts of carbonate of lead and considerable amounts of hydrous silicate of zinc are mined. In former years, the relative amounts of the oxidised compounds were much greater. The lead- and zinc-minerals are accompanied by iron and copper sulphides with their carbonate and oxide derivatives; but the quantities of the copper minerals are very small. Dolomite is constantly found in large quantities, and both baryte and quartz (crystallized) locally occur in notable quantity. A black, recently deposited chert is an exceedingly common gangue-mineral. Cadmium sulphide is not infrequent. The ore-bodies are large in size, but discontinuous and

very irregular. This has had an important influence upon mining operations, there having been many small mines of short life. The general character of the mine-plants is shown in Figs 9 and 10.

There are three common classes of ore-bodies :—

(*a*) The first class of ore-bodies comprize those in which the lead and zinc occur exclusively as sulphides, and usually thoroughly mingled. They are accompanied by marcasite, pyrite and chalcopyrite. Pink crystallized dolomite and occasionally small crystals of quartz occur in abundance. Adjacent to the ore-bodies, a grey massive dolomite has developed from the limestone. The ore-bodies are traversed by open water-channels and show many vughs, varying in size from small openings to those several feet across. These channels and vughs are lined with beautiful crystals of the various minerals enumerated, and with these calcite is abundant. The water found in connection with the ore-bodies of the first-class is clear as crystal, and the flow bears no relations to

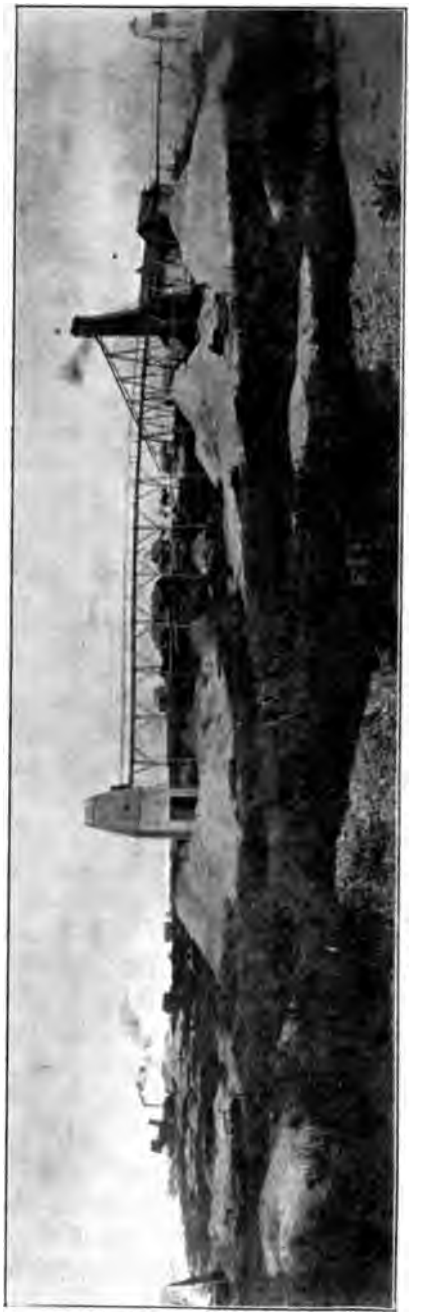

FIG. 10.—ZINC-MINES NEAR JOPLIN, MISSOURI, ILLUSTRATING TWO SHAFTS DELIVERING ORE BY AN ELEVATED TRACK TO A CONCENTRATING-MILL.

local rainfall or seasonal changes. All such ore-bodies are below the normal underground water-level, and at greater depth than the second and third classes described below. As will be later explained, these ore-bodies represent the first or original concentration of the ore.

(*b*) Above the ore-bodies just described, at and extending for some distance below water-level, are ore-bodies of a second class. These are largely composed of sphalerite. In all cases this mineral is notably dominant. They are normally considerably richer than the ore-bodies just described. The ground is softer and requires more timbering. The water may be dirty, and in some instances varies in quantity. In certain cases, in vughs and cracks in the ore, there is a secondary deposition of the sulphides, the latter occurring either in well-defined crystals or as a cement joining fractured portions of the original ore. In certain cases, notably in the mines of the Boston-get-there Company, mingled with these secondary or recent sulphides are crystals of siderite. These ore-bodies are those now most frequently worked, and, as fully explained later, are believed to represent original ore-bodies enriched by secondary deposition of sulphides.

(*c*) The third class of ores are those above water-level, or in some instances in part slightly below that level. These ores consist essentially of either galena or calamine. The ground is either dry or muddy. Red clay is the most constant gangue. The beautiful crystals found in the ore-bodies first described are relatively rare. The amount of water handled by the mine-pumps is closely dependent upon seasonal variations and local rainfall. Such carbonate of zinc and lead as occurs is found in connection with these ore-bodies. Baryte is also found with them. Stains of copper carbonate are not infrequent. As explained later, these ore-bodies are believed to represent the accumulations due to oxide-enrichment. They are broadly equivalent to the usual gossan of metalliferous veins.

The forms of the ore-bodies are conditioned by the form of the openings produced by fracture and solution, as already explained, and the extent to which the metal-bearing solutions penetrating the surrounding limestone have metasomatically replaced the latter. As already indicated, the normal form of ore-body is exceedingly irregular. This does not, however, preclude the occurrence of exceptional, relatively regular, ore-bodies. The ore-deposits of the Boston-get-there mine (Fig. 11) represent one of

the common regular forms known locally as "sheet-ground." In this instance, the ore-bearing solutions have spread out along bedding-planes in the top of a great body of chert. The result has been the formation of a great blanket-deposit, 10 to 20 feet thick. The whole is mined, except where it is necessary to leave pillars to support the limestone-roof.

The vertical distribution of the ores is that common in the lead- and zinc-districts of the entire Mississippi valley. The carbonates, silicates and oxides, where they occur, are found above or near water-level, and constitute the highest portion of the ore-bodies. Below them the sulphides are found. To a limited extent, the sulphides are mingled with the carbonates and silicates, the line of demarcation not being everywhere sharp. It is noteworthy that of the sulphides thus mingled, galena is the most frequent. The sulphides commonly exhibit a vertical order among themselves, there being three zones in which galena, blende and iron sulphides become in turn dominant with increased depth.

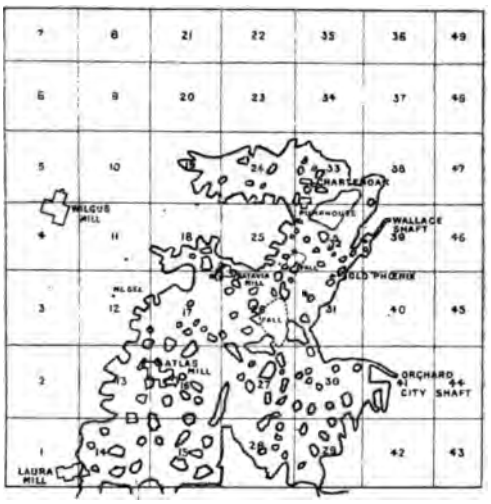


FIG. 11.—PLAN OF THE BOSTON-GET-THERE ZINC-MINES, PROSPERITY, MISSOURI.
SCALE, 530 FEET TO 1 INCH.

The zone of dominant iron sulphides has not as yet been generally penetrated in this district. Indeed, throughout the district iron sulphides are very much less abundant than is common in other districts. Below the three zones mentioned, where the three sulphides are thoroughly mingled, in this district zinc sulphide seems usually dominant.

### 3. Genesis of the Ores.

In making a statement as to the genesis of the ores, it will be necessary to state the theory somewhat briefly and to refer to other papers* for many of the details which support it.

* "Some Principles controlling the Deposition of Ores," by Prof. C. R. Van Hise, *Transactions of the American Institute of Mining Engineers*, 1901, vol. xxx., pages 27 to 177. "The Lead and Zinc-deposits of the Ozark Region," by Mr. H. F. Bain, *Twenty-second Annual Report of the United States Geological Survey*, part ii., pages 203 to 215.

It will be convenient to consider separately the three classes of ore-bodies already described.

(*a*) Ores of the First Concentration.

A brief field-study makes it clear that the ores of the first class as well as the derived ores of the second and third classes, were deposited from solutions. The reasons for this are so obvious to any student of ore-deposits, who has followed the descriptions given, that it is merely necessary to mention the matter. In every case the ore-bodies are found where there is the clearest evidence of the movement and mingling of considerable bodies of solutions. In sedimentary, undisturbed rocks, such as those of the Mississippi valley, all theories of ore-deposition by sublimation, pneumatolytic action and magmatic differentiation may be at once rejected. The whole of the evidence points to the ores being deposited from the dilute solutions which constitute the ground-water of the district. The precipitation of ores was mainly accomplished by the mingling of solutions at places where ground-waters of different constitutions met. This is perhaps clearest in the case of the ores of the first class. It has already been explained that while the ore-bodies occur mainly in the Carboniferous Limestone, no ore-bodies have been found except in areas where there was opportunity for a mingling of the ground-waters of the Carboniferous and the Cambro-Silurian limestones. The Carboniferous Limestone has been almost completely re-crystallized, and in part at least the older or white chert which is interbanded with the limestone has been developed in it by replacement. These changes occurred anterior to the development of the ore-bodies, and were apparently wholly independent of the processes which developed the ores. There was early, a far-reaching and long-continued circulation in the Carboniferous rocks, which brought about many changes in the limestones and cherts of that formation. So long, however, as there was no connection with the deeper circulation of the Cambro-Silurian, neither dolomite nor ores were developed. This is shown by the fact that in the Mississippian limestones outside the Missouri-Kansas district, in areas where connection with a possible circulation below has never been established, there is a similar re-crystallization of the limestone with the development of chert-nodules and concretions but no ore or dolomite. So long as the circulation was confined

to Carboniferous rocks there was no deposition of ore. Only when opportunity was afforded, by deep fault-planes cutting the intervening shale, for the waters of the Cambro-Silurian to rise and mingle with the waters above, was there any considerable ore-deposition; and it is an interesting confirmation of the correctness of this view that dolomite is a constant accompaniment of the ore. Wells penetrating the Carboniferous rocks, away from the ore-bodies yield water practically free from magnesia. Those penetrating the Cambro-Silurian show that the water is notably charged with magnesia.* This indicates that both the magnesia and the metals now found in the ore-bodies were brought into the Carboniferous rocks from or through the Cambro-Silurian below.

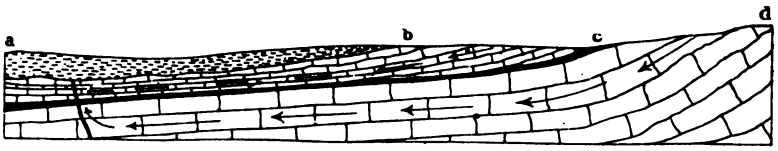


FIG. 12.—IDEAL SECTION INDICATING THE COURSE OF UNDERGROUND WATERS IN THE MISSOURI-KANSAS DISTRICT.

At an earlier period, before the overlying Coal-measure shales were cut through, the general underground circulation was as indicated in Fig. 12. A portion of the water falling on the surface, between *c* and *d*, sank into the ground and took the course indicated by the arrows. As it travelled down the dip, there was an accumulating hydrostatic pressure which tended to force up the water. The overlying impervious Eureka-Kinderhook shale prevented an actual upward flow, until the faulted area near Joplin was reached, where the water passed upward along the fault-planes as indicated. The water falling on the surface, between *b* and *c*, likewise passed down the dip and was prevented from flowing out on the surface by the overlying shale. The water accordingly met and mingled with that rising along the fault-planes. At the point of deposition, there were accordingly two classes of waters, one being ascending and the other moving laterally. If the whole course of either current be taken into account, each will be recognised to have been descending. From any point of view, the major movement is lateral. It is noteworthy that each stream of water

* See analysis in "The Geology of Benton County," by Messrs. F. W. Simonds and T. C. Hopkins, *Annual Report of the Arkansas Geological Survey for 1891*, 1894, vol. ii., pages 19 *et seq.*

derived its motion from gravitative stress. It is also noteworthy that the waters now are, and so far as there is any evidence, always have been at ordinary temperatures. In the journey outlined, neither stream of water reaches depths sufficient to result in any notable increase of temperature. Neither is there any known intrusion of igneous rock in the region which, if present, might have influenced the temperature of the underground water. The circulation outlined represents, in the main, the circulation now obtaining. The differences will be noted later.

It will be here assumed that the metals were derived from the Cambro-Silurian limestone. Evidence on this point is given in the general discussion at the end of this paper. It will there be seen that the metallic sulphides were originally precipitated from the Cambro-Silurian seas. Thus, they were deposited in the Cambro-Silurian limestone in widely dispersed, minute particles.

The chemical processes involved in the segregation and deposition of the ores are believed to be as follows: —

Rain-water falling upon the area of the Cambro-Silurian outcrop is charged with oxygen, and as it passes into and through the rocks this oxygen reacts upon the sulphides of lead, zinc and iron, producing sulphates.

Once oxidized, these metals are taken into solution; for zinc sulphate is very soluble, and lead sulphate, while considered insoluble in the laboratory because at 15° Cent. only about 1 part in 31,000 is dissolved in pure water, is amply soluble so far as the transfer and concentration of lead by underground waters are concerned. It is probably very uncommon for the ore-bearing solutions of the first concentration to carry so much of the metal as 1 part in 100,000.

Rain-water falling upon the area of outcrop of the Carboniferous Limestone expends its oxygen in oxidizing some of the large quantity of asphalt and other organic matter which it meets in its course. But the oxygen is exhausted in the early part of the journey. Organic compounds are then taken into solution. Also one of the most common, if not the invariable accompaniment of waters which have traversed carbonaceous beds, is hydrogen sulphide: this compound being produced by the interaction of the organic compounds and original sulphides, of which the most common is iron sulphide. The water-currents of the Carboniferous Limestone are therefore reducing in character, due both to the organic matter carried and to the hydrogen sulphide contained.

The sulphates formed in the Cambro-Silurian, taken into solution by the underground water, are carried westward, and finally upward to the point of deposition. The long portion of the journey is in the Cambro-Silurian. Opportunity is afforded for the water to deposit its metallic load so soon as reducing agents find it. This is when the water leaves that formation, as is shown by the ores at Granby and elsewhere in the Kinderhook. At the very first contact with the organic matter, widely distributed through these shales and the overlying Carboniferous Limestone, deposition began. We conclude therefore that the Cambro-Silurian limestone was the main original reservoir from which the underground solutions derived their metallic contents.

When the waters of the Carboniferous Limestone meet and mingle with the ascending waters of the Cambro-Silurian limestone, the lead and zinc sulphates are precipitated as sulphides. This is largely due to the direct abstraction of the oxygen of the sulphates by carbonaceous material, it being thus oxidized and the lead and zinc being reduced to and thrown down as sulphides. Also the lead and zinc may be partly precipitated as the result of the action of the hydrogen sulphide. The reactions in this case may be expressed as follows:—$PbSO_4 + H_2S = PbS + H_2SO_4$; and $ZnSO_4 + H_2S = ZnS + H_2SO_4$. The sulphuric acid would react in the presence of limestone and water as follows:—$H_2SO_4 + CaCO_3 + H_2O = CaSO_4 2H_2O + CO_2$. The gypsum being soluble is ordinarily carried away at once in solution. In a few instances some remains behind.

It is not necessary to believe that the ores were entirely precipitated from sulphates. Such a derivation is, however, the simplest hypothesis, and the one which best accords with the facts of the field. In small part, the ores may have been transported as chlorides or carbonates, and in fact there are a large number of possible chemical combinations available.

The ores of the first concentration were deposited in the presence of an excess of precipitating agents. There was more than a sufficient amount of organic material and of hydrogen sulphide to throw down all the metallic compounds; and hence all the sulphides precipitated were intimately mingled. The sulphides thus precipitated were not deposited to an unusual degree contiguous to the black shales of the Eureka-Kinderhook and of the Coal-measures. The probable reason for this is that the precipita-

tion was mainly caused by the solutions, and not by the solid organic matter of the shales. The broken and porous limestone gave much larger openings for the mingling of the solutions and the precipitation of the ores than the plastic shales.

The time of the deposition of the ores of the first concentration is not well fixed. It began after the deformation which fractured and faulted the limestones, and which cut the Eureka-Kinderhook. It seems reasonable to correlate this event with the uplift of the Ozark dome. This movement has been placed by Mr. C. R. Keyes* at the beginning of the Tertiary. This is, however, admittedly uncertain. The deposition continued from that time onward, and since the general movement of the underground water in the district is to-day substantially the same as indicated, it is probable that ores of the first concentration are still being deposited.

### (*b*) Enriched Sulphide-ores.

An important counter-movement of the waters has, however, been in play since the extensive removal by erosion of the cap of Coal-measure shales and limestones. It has been the work of this counter-movement to produce a reconcentration, and the enrichment of the upper sulphide bodies. Other results of this movement have been the production of an orderly vertical arrangement of the ores, and the accumulation of the carbonates, silicates and oxides in the superficial zone.

When, in consequence of erosion, the sulphides of the first concentration rise above the level of the ground-water, they are in the belt of oxidation and are slowly oxidized to sulphates and carbonates. During the formation of sulphates and carbonates, a portion of these salts is dissolved, carried below the level of underground water and reprecipitated as sulphides. They thus contribute to the value of the ores found at and for some distance below this level, and produce a notable enrichment of the ores of this zone. In part, the process is identical with that already discussed in connection with the first concentration of the ore: the difference being that in this case the sulphates are carried downward from above rather than upward from below. In both cases, the organic matter and the hydrogen sulphide present

* "Characteristics of the Ozark Mountains," by Mr. C. R. Keyes, *Missouri Geological Survey*, 1893, vol. viii., pages 351 to 352.

in the solutions of the Carboniferous Limestone are reducing agents. As in the case of the first concentration, sulphates are reduced to sulphides by the organic matter, and the various salts of lead and zinc are precipitated by hydrogen sulphide. Both of these reactions result in sulphide-precipitation and enrichment.

But there is another important series of reactions due to the reducing action of the sulphides themselves, the chief being that between lead and zinc salts and iron sulphide. First, considering the case of lead, and supposing the iron to be in the form of sulphide of iron, the reactions may be written as follows:—$PbSO_4 + FeS = PbS + FeSO_4$; and $PbCO_3 + FeS = PbS + FeCO_3$.

If the iron be in the form of $FeS_2$, as is most likely, oxygen would be necessary for the reactions. The equations would then be as follows:—$PbSO_4 + FeS_2 + O_2 = PbS + FeSO_4 + SO_2$; and $PbCO_3 + FeS_2 + O_2 = PbS + FeCO_3 + SO_2$.

Since zinc sulphide is also present and reacts in a corresponding manner on lead salts, the following reactions may also be supposed to take place:—$PbSO_4 + ZnS = PbS + ZnSO_4$; and $PbCO_3 + FeS_2 + O_2 = PbS + FeCO_3 + SO_2$.

In the case of the latter reaction, smithsonite would be formed; and it is noteworthy that not only in this district, but throughout the Mississippi valley there is a common association of smithsonite and galena.

The relations between iron sulphide and the zinc compounds correspond to those between zinc sulphide and the lead compounds. According to the extent to which the zinc carbonate and sulphate produced by the reactions noted above, or the corresponding compounds produced in the zone of oxidation, are carried down by the waters, there would be a series of reactions as follows:—$ZnCO_3 + FeS = ZnS + FeCO_3$; and $ZnSO_4 + FeS = ZnS + FeSO_4$.

Since of the three metals, lead, zinc and iron, the first has the greatest affinity for sulphur, the second the next greatest, and the last the least, in the presence of downward moving oxygenated waters, the final result of all the reactions is the orderly vertical arrangement of the sulphides already noted as characteristic of this district; that is, galena, blende and iron pyrites successively dominant in depth. Owing to the small amount of iron sulphide present in the district it is unusual here, although common in other mining districts, for the iron actually to dominate the other minerals in depth. Such dominance has, however, been noted in

deep drilling at Granby, Missouri, and an increase in the amount of iron sulphide present is noticeable at many points.

The general process of secondary enrichment of sulphide ore-bodies, and the reactions of the sulphides toward each other, has recently been discussed in some detail by Messrs. Van Hise, Emmons, Weed, and others.* It is not intended here to discuss the process farther than its application to the ore-bodies of the region discussed. The widespread orderly vertical arrangement of lead and zinc sulphide bodies indicates, however, that the process has been an important one in the genesis of these ores.

### (*c*) The Oxidized Ores.

The ores of the third class, the oxidized ores, include essentially those above or near the underground water-level. They comprise oxides, carbonates, silicates, sulphates, and occasionally chlorides and other rare combinations. These ore-bodies have been formed from the sulphide-bodies after the overlying impervious shale had been cut away, so as to allow a local downward flow of surface-waters containing oxygen. They are the result of direct oxidation of sulphide ore-bodies of classes (*a*) and (*b*). Their richness is partly due to residual concentration, that is, is due to enrichment which results from the removal by the ordinary process of erosion of the more destructible gangue and country-rock. The formation of the oxidized ores has taken place mainly above the level of the underground-water; since below that level there is usually an excess of organic matter, and hence the medium is reducing. The changes due to oxidation, carbonation, hydration and solution, are coincident with the elevation of the sulphides above the level of the ground-water, in consequence of progressive denudation. Lead sulphide (PbS) and zinc sulphide (ZnS), by simple oxidation are changed to lead sulphate ($PbSO_4$) and zinc sulphate ($ZnSO_4$). The lead sulphate constitutes the mineral anglesite. If this sulphate reacts upon calcium carbonate, lead carbonate and hydrated calcium sulphate are produced according to the following equation:—$PbSO_4$ +

* "Some Principles controlling the Deposition of Ores," by Prof. C. R. Van Hise, *Transactions of the American Institute of Mining Engineers*, 1901, vol. xxx., pages 27 to 177. "The Secondary Enrichment of Ore-deposits," by Mr. S. F. Emmons, *Ibid.*, pages 177 to 217. "Enrichment of Gold- and- Silver-veins," by Mr. W. H. Weed, *Ibid.*, pages 424 to 448. Also, "Enrichment of Mineral Veins by Later Metallic Sulphides," *Bulletin of the Geological Society of America*, 1900, vol. xi., pages 179 to 206.

$CaCO_3 + 2H_2O = PbCO_3 + CaSO_4 2H_2O$. In this manner, cerussite, formerly extensively mined in this district, was formed.

If the zinc sulphate reacts on calcium carbonate, smithsonite is produced, according to the following reaction:—$ZnSO_4 + CaCO_3 + 2H_2O = ZnCO_3 + CaSO_4 2H_2O$.

In this district, the bulk of the zinc sulphide seems to have been altered to the silicate $[(ZnOH)_2SiO_3]$. Silica in chert is abundant in the district, and this, in the presence of zinc sulphate and water, reacts as follows:—$SiO_2 + 2ZnSO_4 + 3H_2O = (ZnOH)_2SiO_3 + 2H_2SO_4$.

The iron present alters to ordinary limonite ($Fe_2O_3 3HO$) and hæmatite ($Fe_2O_3$), in the latter form giving the red colour to the gangue-clays, which is characteristic of the ore-bodies of this zone. Basic ferrous sulphate is a common bye-product.

### 4. Recapitulation.

The ore-bodies of the Missouri-Kansas district consist essentially of lead and zinc sulphides, with minor amounts of carbonates, silicates, etc. These ore-bodies chiefly occur in the Carboniferous Limestones and chert, which are capped by erosion-remnants of Coal-measure shales and sandstones, and are underlain by the Eureka-Kinderhook shale, which cuts them off from the Cambro-Silurian dolomites below. The beds have a gentle dip to the north and west, and the older beds crop out at higher altitudes than the younger. The ores were deposited from the underground-water solutions. These waters were in circulation, the motive power being gravitative stress, and the deposition occurred mainly as a result of the mingling of solutions, the sulphate solutions of the Cambro-Silurian passing up through the Eureka-Kinderhook, along fault-planes, and mingling with the reducing solutions of the Carboniferous Limestones. The ores were originally deposited as sulphides, and have since been reconcentrated by the downward flow of surface-waters with the production of an upper surface-zone of carbonates, silicates, etc., and a middle zone of enriched sulphides. Another result has been the production of an orderly vertical arrangement of the sulphides.

## C. *South-eastern Missouri District.*

In the South-eastern Missouri district the ores occur in the Cambro-Silurian limestone, which rests upon Cambrian sand-

stone, which in turn reposes upon pre-Cambrian rocks. While the fact has not been previously emphasized, shales occur frequently in the lower part of the Cambro-Silurian limestone, some distance above the Cambrian sandstone. The productive area is limited by an escarpment of Carboniferous Limestone, and at an earlier period this limestone, with Kinderhook shales at its base, doubtless covered the district. The ore-deposits occur in the Cambro-Silurian limestone associated with and overlying the shales belonging to the lower part of this limestone. The rocks have a dip away from the Archæan core to the Missouri and Mississippi rivers; that is, to the north, east and north-east. It, therefore, appears that the general facts in this district are remarkably similar to those in the Missouri-Kansas district.

As to the character of the ores, there are two distinct sub-districts in which the occurrences are markedly different. Following Mr. Winslow's classification,* the first of these is the St. François and Madison counties sub-district; and the second includes the Washington and Franklin counties sub-district, that is, the remainder of the South-eastern district. The latter sub-district will be considered with the Central district.

The first sub-district, that of St. François and Madison counties, contains the largest and most important lead-mines of Eastern Missouri. Mr. Winslow describes five camps in this sub-district, namely, (1) Mine La Motte, (2) Bonne Terre, (3) Flat River, (4) Doe Run and (5) Avon.† At all of these areas the ores are galena. The galena, for the most part, is disseminated through solid crystalline limestone, in many cases rather evenly, but in some cases, as in the Mine La Motte deposits, "grains of galena are frequently strung-out along the stratification, sometimes so close together as to form sheets, which vary in thickness from one-tenth to several inches."‡ Disseminated galena is also found as a matrix of conglomerate between boulders at the Doe Run mines.§ The Mine La Motte disseminated ores occur principally at two horizons. "The limestone of the upper horizon is known as the 'black rock,' of the lower as the 'white rock'; the ore is more persistent in the 'white rock.'"¶ Blende is very subordinate, and at the Bonne Terre camp "absolutely no zinc occurs, not even enough to be detected by analysis."‖

* "Lead- and Zinc-deposits," by Mr. Arthur Winslow, *Missouri Geological Survey*, 1894, vol. vii., page 645.

† *Ibid.*, page 646. ‡ *Ibid.*, page 653. § *Ibid.*, page 673.

¶ *Ibid.*, page 653. ‖ *Ibid.*, page 666.

In the Mine La Motte and Flat River areas, the ore is notably rich at the lower part of the magnesian limestone, where there are interstratified layers of slate. In some of the camps, early workings developed concentrated deposits of galena in crevices. For instance, at the Bonne Terre, "near the surface concentrated deposits of galena were found in crevices; and in the days of early mining these were the principal ores worked . . . . Several such crevices were developed and worked here, but they were all found to grow narrower, and to become unproductive with depth."* At the Flat River mines also "large amounts of massive galena were mined from crevices by shallow diggings."† But at present the ore "consists principally of galena disseminated through magnesian limestone,"‡ and these disseminated ores are at a greater depth than the galena in the crevices. The early workings also developed considerable cerussite, as for instance, at the Mine La Motte and Bonne Terre mines. The associated ore-bearing minerals are iron-pyrites and copper-pyrites, and cobalt sulphide and nickel sulphide. It is notable that the copper-pyrites carrying workable amounts of nickel and cobalt at Mine La Motte are found in the upper of the two horizons at which the ore occurs—the "black rock," rather than the "white rock." Also at the Bonne Terre mines, "the copper-pyrite and pyrrhotite, carrying about 4 per cent. of nickel and cobalt, characterized the upper workings down to a depth of 100 feet or so; although such ores are reported as occurring at lower levels."§ As in the south-western district of Missouri, pyrite is subordinate in quantity.

The chief gangue-minerals are calcite and dolomite, and it is notable that baryte is absent, although so abundant in the second sub-district of South-eastern Missouri and in the Central district.

The first four of these groups of mines are among the deepest lead- and zinc-mines of the Mississippi valley. For instance, the ores of the Mine La Motte area are mostly found between 70 and 150 feet from the surface.¶ The richest horizons of the Bonne Terre area are between 150 and 250 feet from the surface.‖ However, in those two areas, the crevice-deposits above described were at higher levels. In the Flat River area, most of the ore is below

* "Lead- and Zinc-deposits," by Mr. Arthur Winslow, *Missouri Geological Survey*, 1894, vol. vii., pages 650 to 669.

† *Ibid.*, page 668. ‡ *Ibid.*, page 668. § *Ibid.*, page 666.

¶ *Ibid.*, page 653. ‖ *Ibid.*, page 666.

the 150 feet level; much of it is between 200 and 300 feet from the surface; and the lower level of the Central Mining Company, is 380 feet deep.* The Doe Run mines are principally between 50 and 90 feet from the surface, but galena has been developed to a depth of 230 feet. Finally, the ores in this district are associated with zones or belts of fracturing and faulting, just as in the Southwestern district.†

It appears clear that these facts indicate two concentrations, the first by a deep circulation mainly between the shales near the bottom of the Cambro-Silurian limestone and the Eureka-Kinderhook shales, and between the lower shale and the underlying crystallines. At the time of this deep circulation, the disseminated ores in the limestones and shales were deposited. The reducing and precipitating agents were clearly derived from the organic matter of the shales and subordinately from the limestone. It is notable that the deposits in which the evidence points to a first concentration, with comparatively little effect by a secondary concentration, occur in the district in Missouri, in whch there has been the deepest mining.

When the overlying shales were removed by erosion, there began the second concentration by descending waters; and at this time the disseminated ores were taken into solution and concentrated in the crevices, as in the Mine La Motte and Bonne Terre areas.

The disseminated lead sulphide of the first concentration was oxidized to sulphate. The sulphate was largely carried downward by descending waters, and by reactions between that compound and the reducing solutions of the ascending currents, or the marcasite, or the organic matter of the formations, or by two or all combined, was reprecipitated as sulphide, thus resulting in a second concentration.

At the upper levels, mainly above the level of the ground-water, lead carbonate (cerussite) was formed by reactions between lead sulphate and calcium carbonate, as already explained. The presence of the rich deposits of copper-pyrites and pyrrhotite carrying workable quantities of nickel and cobalt at Mine La Motte and Bonne Terre at the upper horizons, and their absence at lower

* "Lead- and Zinc-deposits," by Mr. Arthur Winslow, *Missouri Geological Survey*, 1894, vol. vii., page 669.

† *Ibid.*, page 673.

horizons, is further evidence of secondary concentration at upper horizons. Indeed, the production of these richer sulphides at higher horizons, and their absence at lower horizons, corresponds precisely to the facts upon which have been based the belief that two concentrations of such deposits have widely occurred; the first by ascending, and the second by descending waters.*

The two exceptional facts of this sub-district, as compared with other districts, are the very great sparseness of zinc-ores and the absence of baryte.

### D. *Central Missouri District.*

With this district will be considered the sub-district of Washington and Franklin counties, belonging to the South-eastern district, since in all essential geological conditions the relations of this sub-district are closer with the Central than with the South-eastern district.

The Central district of Missouri and Washington and Franklin counties show the same geological succession as St. François and Madison counties. The occurrence and character of the ores are, however, very different. As shown by Mr. Winslow's† descriptions and figures, the ores occur almost exclusively in crevices, pitches, flats and caves. The occurrences of the ores are practically identical with those of Wisconsin, described by Prof. Chamberlin,‡ many years earlier, but here later considered. The ores occur lining the walls of the openings, or detached from them by solution. The mines are mostly shallow, nearly all less than 100 feet, being mainly above the level of the ground-water. In this respect also they are identical with the Wisconsin district, at the stage of development when Prof. Chamberlin described it. Moreover, the ores are of the same kind as they are in Wisconsin near the surface, that is, the ores are oxidized lead and zinc products and galena, and in this respect are identical with the Wisconsin ores. Thus, at the Jumbo shaft, dry bone and cerussite were found near the surface.§ At the Valle mines, a very large amount of zinc-ore

* "Some Principles controlling the Deposition of Ores," by Prof. C. R. Van Hise, *Transactions of the American Institute of Mining Engineers*, 1901, vol. xxx., pages 109 to 114.

† Mr. Arthur Winslow, *cit.*, vol. vii., pages 677 to 722.

‡ "The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., pages 451 to 482.

§ Mr. Arthur Winslow, *cit.*, vol. vii., page 683.

has been mined, mostly as carbonate but to some small extent as silicate.* In some places, as for instance at Lee's diggings, pyrite is found below the galena.† Up to the present time, the amount of blende is subordinate, but it occurs to some extent associated with the galena. Workings as yet have not in general gone deep enough to show whether or not blende-deposits usually exist below the galena horizon, as in the Missouri-Kansas district. But important bodies of blende have already been developed at this horizon in the Meremac mine in Washington county and several mines in Morgan county. In most marked contrast with the mines of St. François and Madison counties, baryte is everywhere abundantly found. Mr. Arthur Winslow's descriptions mention baryte as a prominent gangue-mineral in almost every mine, and in a number of places it is so abundant as to become a valuable bye-product, as at Belfontain, Kingston and the Parole mines. Potosi and Mineral Point are important shipping-stations for this mineral.

The lithological succession of the Central district of Missouri and of Washington and Franklin counties, the position of the ore-bearing strata between impervious shales, the correspondence of the inclination of the beds and the drainage, and the fact that this inclination is greater than the slopes so as to cause lower horizons to crop out at the higher elevations, the manner of the occurrence of the ores, and the nature of the ores themselves, are all very like the Missouri-Kansas district already described; and still more like, indeed almost identical, with the upper district of Wisconsin, Illinois and Iowa, to be later considered. If the explanation of two concentrations, one by a deep circulation while the overlying shale was mainly above the ore-bearing strata, and a second concentration by descending waters after the impervious strata were removed, be correct for the Missouri-Kansas district, it is sure to apply to the portion of Missouri under discussion.

However, by comparing these districts with the St. François and Madison counties sub-district in Missouri, we note additional links in the chain of evidence for two concentrations. The relative sparseness of zinc-ores in the St. François and Madison counties sub-district has been emphasized.‡ Also the almost universal absence of baryte has been noted. But it has been explained of the central

* Mr. Arthur Winslow, *cit.*, vol. vii., page 687.

† *Ibid.*, page 690.

‡ *Trans. Inst. M.E.*, 1902, vol. xxiii., page 402.

district and of Washington and Franklin counties that the zinc-product is very considerable; and that baryte is universally present and at many of the mines exceedingly abundant. It has been pointed out,* that the occurrences in St. François and Madison counties indicate that the deep disseminated ores are mainly the product of a first concentration by a deep circulation. The ores were mainly precipitated where they are, by the reducing action of the solutions produced by the organic material. Under these circumstances, there would be no reason for the formation of baryte. It is believed that the relative unimportance of the zinc is explained by the fact that the first concentration was not sufficient to produce large quantities of these ores. However, in the Central district, and in Washington and Franklin counties, a second concentration by descending waters became the controlling factor in the present location and distribution of the ores. Here, a second concentration produced zinc carbonate in sufficient abundance to be mined and also concentrated the lead, mainly as galena.

If barium were present as a constituent of the associated rocks, so that barium salts would be carried by the underground solutions, the formation of the gangue-mineral baryte would be an incident of the second concentration. When the lead and zinc sulphide of the first concentration formed below the level of the ground-water, came above that level as a result of denudation they were oxidized to sulphates, as already explained. Also, it has been seen that these compounds react upon the alkaline-earth carbonates, producing carbonates of lead and zinc and sulphates of the alkaline earths.

Simultaneously the associated cerussite and smithsonite would be formed. Supposing the barium were in the form of carbonate, the reaction would be as follows:—$PbSO_4 + BaCO_3 = BaSO_4 + PbCO_3$; and $ZnSO_4 + BaCO_3 = BaSO_4 + ZnCO_3$.

If the barium were in some other form than carbonate, the reactions would also involve the carbonates of the other alkaline earths, calcium and magnesium, but the results would be the same so far as the barium is concerned. Ordinarily, the chief sulphate of the alkaline earths, formed as an incident to the development of cerussite and smithsonite, is gypsum. But where barium is present the sulphate of this metal would be precipitated because it is so much more insoluble than calcium sulphate. That barium

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 404.

was contained in the solutions in this district is evidenced by the abundant development of baryte as a gangue-mineral where a secondary concentration by descending waters has taken place. In this connection it is suggested that an investigation of the character of the limestone of the Eastern Missouri district will show that barium is a more important constituent than in Southwestern Missouri or in the Upper Mississippi valley, where baryte as a gangue-mineral is subordinate.

FIG. 13.—CHARACTERISTIC ORE-BRECCIA FROM THE MICHIGAN MINE, BUFFALO, NORTH ARKANSAS.

### E. *North Arkansas District.*[*]

The ores of the North Arkansas district may be classed as (1) crevice-deposits; (2) breccia-deposits, representing zones of crushing in limestone or in limestone-conglomerate; and (3) disseminated ores in limestone or limestone-conglomerate. All of these deposits are in the Cambro-Silurian limestone. The crevice-deposits are similar to those of Central Missouri. The breccia-deposits, which are now the chief source of ore, have formed along

[*] "The Zinc- and Lead-region of North Arkansas," by Dr. J. C. Branner *Annual Report of the Arkansas Geological Survey for 1892*, 1900, vol. v., pages 1 to 393.

zones of crushing. The character of these breccias is illustrated in Fig. 13, in which the dark fragments are pieces of the original country rock. The matrix is secondary dolomite, in which the blende is crystallized. The disseminated deposits are in the solid limestone, or the comparatively unaltered conglomerates. The ores comprise both lead and zinc, the latter being very important. Zinc occurs both as sphalerite and as smithsonite.

Dr. Branner* strongly insists that the ores are largely concentrated in local synclines, and that the anticlines are relatively barren, a relationship previously made out in Wisconsin by Prof. T. C. Chamberlin.

It is not possible to make any positive statements, at the present time, as to the manner of concentration of these deposits. Nevertheless, it seems highly probable that in this district, as in the others of the Ozark region, there have been two concentrations: (1) by a deep-seated artesian circulation, and (2) later concentration by descending water.

In the present state of knowledge no definite opinion can be expressed as to the relative influence of these two circulations; but it may be suggested that the rather large areas of disseminated ores in the compact limestone and unbroken conglomerate represent the work of a first concentration, and that the deposits containing oxidized ores associated with the sulphides in the crevices and breccias have undergone an important secondary concentration by descending waters.

## V.—The Upper Mississippi Valley Region.

### *Wisconsin-Iowa-Illinois District.*

In the region of the Upper Mississippi valley, there is only one district, that of Wisconsin-Iowa-Illinois.

This district was the first one in the Mississippi valley to be extensively studied, and nearly every notable advance in the genesis of the ores has been first worked out in this district. The early studies by Mr. J. D. Whitney,† followed by those of Prof.

* Dr. J. C. Branner, *cit.*, page 32.

† *The Metallic Wealth of the United States*, by Mr. J. D. Whitney, Philadelphia, 1854, pages 403 to 417. "Report of the Geological Survey of Iowa, 1855-57;" and "Chemistry and Economic Geology," by Mr. J. D. Whitney, *Geology of Iowa*, 1858, vol. i., part 1, pages 286 to 295 and 422 to 471. "Report on the Lead-region of Wisconsin," by Mr. J. D. Whitney, *Geological Survey of Wisconsin*, 1862, vol. i., pages 73 to 424. "Geology of the Lead-region of Illinois," by Mr. J. D. Whitney, *Geological Survey of Illinois*, 1866, vol. i., pages 153 to 207.

T. C. Chamberlin,* in particular have done much to make clear the origin and nature of these ore-bodies.

As the result of the most excellent work of the Second Wisconsin survey under Prof. T. C. Chamberlin,† and the later work of the Iowa Survey,‡ we give the descending succession in the lead- and zinc-districts of the Upper Mississippi valley as follows: —

Cincinnati shale, originally 200 feet thick (in Iowa called the Maquoketa shale).

Galena limestone, bearing organic matter, 450 feet thick.

Trenton limestone, bearing organic matter, 40 to 100 feet thick, with a mean of 70 feet, having at its top an oil-bearing shale§ "2 or 3 to several feet in thickness at points," and containing throughout its mass various shaly layers, which, however, are "quite decidedly most prevalent near the base of the formation."‖

Generally at the base of the Trenton is "a greenish-blue clay, usually from 1 to 2 feet thick. The clay is very finely laminated, and consists of argillaceous and calcareous matter."¶

St. Peter's sandstone, 50 to 150 feet thick.

Lower Magnesian limestone, 100 to 250 feet thick.

Potsdam sandstone, 700 to 800 feet thick.

Pre-Cambrian.

It is to be noted that the Galena limestone is bounded by shales above and below, and that the same statement applies generally but not universally to the Trenton limestone. It is well known that shales are impervious to underground-water circulation. As to the impervious character of the thick Cincinnati shale above the Galena there is no doubt. One might, however, question the im-

* "The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., pages 365 to 572.

† Prof. T. C. Chamberlin, *cit.*, page 412.

‡ "Lead- and Zinc-deposits of Iowa," by Mr. A. G. Leonard, *Iowa Geological Survey*, 1897, vol. vi., pages 20 to 23.

§ "Wisconsin Lead- and Zinc-deposits," by Mr. W. P. Blake, *Bulletin of the Geological Society of America*, 1894, vol. v., pages 28 to 29; also, "The Lead- and Zinc-deposits of the Mississippi Valley," by Mr. W. P. Blake, *Transactions of the American Institute of Mining Engineers*, 1894, vol. xxii., pages 629 to 632.

‖ Prof. T. C. Chamberlin, *cit.*, page 409.

¶ "Geology and Topography of the Lead-region," by Mr. Moses Strong, *Geology of Wisconsin*, 1878, vol. ii., page 683.

erviousness of the thin beds of shale at the top and the bottom of ıe Trenton, but that the upper at least is relatively impervious is ıdicated by the fact that in the Shullsburg and other districts, ı pointed out by Mr. W. P. Blake,* the ore-deposits frequently op at the top of this layer. While the impervious shales of the renton are prominent at the top and near the bottom of the Tren- n limestone, there are also more or less impervious layers within .e limestone itself. The general similarity of the lithological quence to that of the Ozark region is striking.

The strata dip to the south-west. Prof. T. C. Chamberlin says r Wisconsin, " the strata on the north side of the lead-region are )0 feet higher than those of the south side, and if traced farther ıe difference in altitude would be found greater. Beds on the ıstern side are 350 feet higher than those on the west side."† uperimposed upon the general south-western monocline of the .strict are a number of subordinate anticlines and synclines, and ıe ores, according to Prof. Chamberlin, are confined mainly to the ·nclines.‡

The rocks are traversed by two complex systems of intersect- ıg vertical joints and in some places by more. Locally, minor ıulting also occurs. The folding and the fracturing of the rittle limestone were simultaneous processes. But, during the eformation, the plastic shales were mainly flexed, although in laces they may have been dissevered by faulting. The time at hich the deformation occurred is not definitely known, but in all robability it antedated the deep erosion and the concentration of res in the district.§

Areally the ores occur to a much greater extent east of the Mississippi river than west of it; that is, mainly east of the prin- ipal line of drainage. As to horizons, by far the greater quan- ity of ores as yet abstracted were found in the Galena limestone.‖ However, considerable quantities of ores have been taken from

* *Transactions of the American Institute of Mining Engineers*, 1894, vol. xxii. page 631.

† Prof. T. C. Chamberlin, *cit.*, page 422.

‡ Prof. T. C. Chamberlin, *cit.*, pages 432-438.

§ " Lead- and Zinc-deposits of the Mississippi Valley," by Mr. W. P. Jenney, *Transactions of the American Institute of Mining Engineers*, 1894, vol. xxii., pages 208 to 209. " Discussion of Mr. Jenney's paper," by Mr. Wm. P. Blake, *cit.*, pages 628 to 629, and Prof. T. C. Chamberlin, *cit.*, pages 427 and 485.

‖ Prof. T. C. Chamberlin, *cit.*, pages 407, 457 and 481.

the Trenton, and subordinate quantities from the St. Peter's sandstone and the Lower Magnesian limestone. The ores occur in the Galena from top to the bottom.

In cases where erosion has not cut deep into the Trenton, the ore-deposits are apt to be found near the overlying Cincinnati shale. For instance, in Iowa, where the shales are close at hand as a continuous formation, Mr. A. G. Leonard states that the ore occurs mostly near the top of the Galena limestone, within the upper 50 or 60 feet.* Where the drainage-lines have cut through the Galena into the Trenton or lower formations, the ores of the Galena are likely, in large measure, to be near the bottom of the formation, and considerable bodies may rest upon the oil-rock which marks the beginning of the Trenton.

The broad facts as to the occurrence of the ores in the limestones are as follows:—

In openings in limestones, lead- and zinc-minerals are associated with marcasite, and some pyrite and chalcopyrite.† Calcite is an abundant gangue-mineral, as would be expected, but it and the other gangue-minerals will not here be taken into account. Since the pyrite and chalcopyrite are very subordinate, they will not again be alluded to. All the sulphide of iron will be referred to as marcasite.

The vertical order of occurrence in the district is commonly as follows:—Above the level of the ground-water in the belt of weathering the dominant valuable minerals are galena and smithsonite. Frequently encrusting the galena, or in crystals upon it, is some cerussite, and less anglesite; with the smithsonite there is some sphalerite. The smithsonite may locally occur to some extent, to a depth as great as 15 to 30 feet below the level of the ground-water; but deeper down the oxidized products almost wholly disappear. The smithsonite below the level of the ground-water is explained:—(1) By the material being often along a main channel of downward percolating waters; (2) by the fact that the level of the ground-water is probably now higher than it once was, as a result of depression and valley-filling at the close of the Glacial Epoch; (3) by the well-known general downward movement of oxidizing water somewhat below the level of the

* "Lead- and Zinc-deposits of Iowa," by Mr. A. G. Leonard, *Report of the Iowa Geological Survey*, 1897, vol. vi., pages 43 and 61.

† Prof. T. C. Chamberlin, *cit.*, pages 380 to 393.

ground-water; and (4) by reactions between the oxidized lead salts and the sphalerite. Below the galena and smithsonite, that is, mainly below the level of the ground-water, is sphalerite, with a large amount of marcasite.

Where the workings have extended to a considerable depth, the sphalerite is subordinate, the dominant sulphide being marcasite; but many of the workings have not pentrated to a sufficient depth to show whether or not this is general. For much of the district the workings have not gone far below the level of the ground-water, and consequently only the smithsonite and galena and the upper part of the sphalerite have been exploited. But during the past few years a considerable number of mines have penetrated 35 to 70 or more feet below the level of the ground-water. In the deeper of these workings, the sphalerite and marcasite are constantly associated, and the smithsonite and the galena are practically excluded. It may be further said that the few workings which have extended below the Trenton oil-rock have shown great proportional increases of marcasite.

While the above general statement is correct for the district as a whole, it must not be understood that a single sulphide occurs at a given level to the exclusion of the others. Indeed, in many cases all the sulphides are found at the same level. Prof. T. C. Chamberlin* states that, in the upper parts of the deposits of the Galena limestone, the order of arrangement of the materials from the walls to the druse is commonly:—(1) Marcasite and (2) galena in cubic crystals. But in many cases, the marcasite has been dissolved between the galena and limestone, thus loosening the galena-crystals. In some cases, also, a later deposit of marcasite coats the galena. Lower in the Galena limestone, the common order from the wall to the druse is:—(1) Marcasite, (2) ferriferous sphalerite, and (3) galena in cubic crystals. In some places there is superimposed upon this succession, the following members:—(4) Ferriferous sphalerite, subordinate in quantity; (5) marcasite; and (6) galena in octahedral crystals, very subordinate in quantity. As a result of working some distance below the level of ground-water, since Prof. T. C. Chamberlin's report was published, it has been ascertained that at these deeper levels the almost universal order from the wall is:—(1) Marcasite; and (2) sphalerite, galena being very subordinate.

* "The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., pages 491 to 497.

It is believed, as fully explained in the general discussion at the end of this paper, that a large part of the material of these ores was once disseminated through the sedimentary rocks, and especially the limestones. The ore-bodies of the district were produced by the concentration of this material in and near the crevices.

Messrs. Whitney and Chamberlin believe that the deposits have been produced by a single concentration, by descending and lateral moving waters traversing the rocks in the immediate vicinity of the ores formed. Prof. T. C. Chamberlin holds that the movement was accomplished by the mingling of waters which came directly from the surface with waters which came somewhat less directly from the surface, moving downward and laterally. He says that:—

> At the time the ore-deposition took place, the openings in which the metals were deposited were being continually supplied with water from the two sources above indicated, namely:—(1) That which entered directly from the surface-opening of the fissure and was charged with organic matter, and (2) that which penetrated through the minute pores and fissures of the rock on either side of the crevice, and, becoming mineralized, found its way into the crevices. There thus came together, (1) water slightly charged with metallic substances, and (2) water slightly charged with organic matter. The result would be the reduction of the metallic compounds to sulphides, by the deoxidizing action of the organic matter.
>
> It would only remain for the metallic sulphides to gather on the walls of the crevice in their appropriate crystalline forms to produce the galenite, blende, pyrite, marcasite and chalcopyrite that formed the original deposit.

However, Prof. T. C. Chamberlin* recognizes that the organic matter in the bed-rocks themselves also served as a reducing agent. Thus is explained the impregnation of the carbonaceous beds with crystals of galena, blende and pyrite.

The above process described by Prof. T. C. Chamberlin is similar in many respects to that already given for the reconcentration or secondary enrichment of the ores of the Ozark region. In the Wisconsin-Iowa-Illinois district, the many analogies of the structural relations of the ores to the containing rocks, the character of the ore-bodies themselves, and the vertical distribution of the ores of different kinds, to those of the Ozark region, give strong reasons for believing that the processes which operated in the latter region were also influential in the former district: that is, there was an early concentration by an artesian circulation,

* Prof. T. C. Chamberlin, *cit.*, page 545.

which produced lean ore-bodies of a greater vertical magnitude than the deposits now existing, and a reconcentration by a shallow circulation. The general character of this earlier circulation, and some of the reasons for believing that it was here influential, may be briefly stated as follows:—

While in the Wisconsin lead-district the Niagara limestone and Cincinnati shale are only found on occasional mounds, as pointed out by Prof. T. C. Chamberlin,* there is no question that these formations once extended over the entire district. As already noted, the Cincinnati shale is an impervious stratum. Until it was cut through by the drainage, it is probable that effective concentration of the ores did not begin. When it was once cut by erosion, the main concentration history of the ore-deposits is believed to have begun. The Mississippi river and areas adjacent were the places where the drainage was the lowest. However, these were not the places first cut through by erosion, for the difference between the level of the Mississippi drainage and the tributaries adjacent is not so great as the dip of the strata to the south-west. In all probability, therefore, the Cincinnati was first cut through, and the Galena encroached upon by erosion north and east of the lead- and zinc-district. This is probable from the fact that, at the present time in the lead-district, the Mississippi river is for the most part on the Trenton limestone, and never reaches deeper than the St. Peter's sandstone; while the majority of the smaller streams in the north-eastern part of the lead-district have cut into the St. Peter's, and the headwaters of some of them, notably the Pecatonica, Platte and Grant rivers, have cut through the St. Peter's into the Magnesian; and still farther to the north-east, north of the divide, occupied by the Lancaster branch of the Chicago and North Western railway, the strong Wisconsin has cut down to the Cambrian.†

It is to be remembered that the pervious strata overlain by impervious strata along the Mississippi river bear water under pressure, as is shown by numerous artesion wells.‡ The feeding area is the higher ground to the north-east. It is highly probable that the broken and consequently porous Galena limestone was a

* Prof. T. C. Chamberlin, *cit.*, pages 410 to 412.

† See *Atlas of Wisconsin*, plates i. and viii.

‡ "Artesian Wells of Iowa," by Mr. W. H. Norton, *Iowa Geological Survey*, 1896, vol. vi., pages 113 to 428.

formation which was capable of carrying water to considerable distances, and in considerable quantities, although probably not comparable in these respects to the St. Peter's or Potsdam sandstones. The lead- and zinc-district of Wisconsin is wholly south of the divide between the Wisconsin river and the tributaries of the Mississippi. When the Wisconsin drainage north of the divide had cut through the Cincinnati shale, this furnished a feeding area to the Galena limestone. When, later, the Mississippi tributaries south of the divide had cut through the Cincinnati shale into the Galena, the waters entering to the north-east and following along the limestone were able to escape to the south-west.

As erosion continued, the area in which the Cincinnati was cut through and the Galena was penetrated gradually extended to the south-west, until the Mississippi itself had cut through the Cincinnati. During this time, the water entered the Galena limestone at the higher elevations, that is, to the north and east, followed along this formation, and escaped at some lower point towards the Mississippi river. While the water to the greatest extent followed the upper portion of the Galena, it is believed that this broken formation, and to an unknown extent all the lower sedimentary formations, were searched to their deepest parts according to the laws of the flow of underground water.

It is well known that during the early part of the journey of underground waters they contain oxygen and, therefore, produce an oxidizing effect upon the compounds with which they come into contact. Also, when the waters first enter the ground they contain no salts in solution and are, therefore, dissolving waters. Waters which have had a long underground journey are apt to be reducing. This is especially likely to be true if they are shut off from the surface by impervious strata. For instance, the artesian waters in the vicinity of Lake Michigan and along the Mississippi river, the feeding area for which is Central Wisconsin, are "marked by slightly sulphuretted waters."*

Concerning the circulation, it is here sufficient to say that the meteoric water entering the earth at innumerable points occupies the entire available cross-section in its journey. In the early part of its course, where it is widely dispersed, its vertical component is downward. This component is superimposed upon a lateral

* "The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., page 547.

component giving resultant curved lines of flow. As the water continues its journey, it is more and more converged into trunk-channels. In the latter part of its journey in these trunk-channels, the vertical component is upward. The lateral component of the journey is frequently a hundred or more times as great as the vertical component. Finally, the upward component of the water in the trunk-channels carries it to the surface, where it escapes.

In the Wisconsin limestone, the trunk-channels through which the water mainly escaped were joints. These joints, in this district, are called "crevices." As already noted, in many parts of the district the crevices occur in two intersecting sets* and at such places of intersection it is well understood by mining-engineers that the ore-deposits are likely to be unusually rich. In the early part of the journey, where the water was recently derived from the surface and was widely dispersed, it has been seen that the waters are oxidizing and dissolving. The conditions were, therefore, favourable to the oxidation of minute dispersed sulphides of lead and zinc to sulphates. Once oxidized, these metals would be taken into solution.

While the lead and zinc have been supposed to be carried as sulphates this is not a necessary supposition, for they may have been transported in part or in whole in other forms. The dissolved lead and zinc would be largely carried to the trunk-channels or their vicinity. Here, where the water was ascending, it is believed that the lead and zinc were largely precipitated as sulphides.

The precipitation of the ores in and adjacent to crevices is believed to have been due to the mingling of solutions adjacent to these trunk-channels. Portions of the solutions furnished the dissolved compounds. Such solutions would be likely to be those which utilized the large opening and which had not come into intimate contact with strata bearing abundant organic material. Other solutions which, in the late parts of their courses, came from limestone or shales containing organic matter were reducing and probably contained sulphydric acid, since, as already noted, the deep artesian waters of the present circulation of the region contain this compound. Other reducing compounds may have been carried in the waters. The mingling of these two classes of solutions in the trunk-channels would throw down the lead and zinc as sulphide, according to the following equation:—$PbSO_4 + H_2S = PbS + H_2SO_4$.

* *Atlas of the Geology of Wisconsin*, plates xxxviii., xxxix. and xl.

It is probable that there was a tendency at the time of this first concentration in the crevices for the sulphides to be thrown down in a more or less definite order across the openings, as indicated by the phenomenon of crustification, although this phenomenon is probably largely explained by a later concentration.

However, the sulphates of lead and zinc of the solutions dispersed through the smaller openings of the rocks were doubtless in part reduced by the direct action of the organic material contained in the shales and limestones. In this case, the precipitated lead and zinc sulphides would be disseminated through the shale and limestone. They would be likely to be most abundant in shales and limestones containing organic matter, adjacent to a trunk-channel which furnished an abundant supply of metals; for a vigorous circulation is necessary to furnish a large supply of metals, and from the trunk-channels waters would continuously make their way into the adjacent carbonaceous rocks. In the lead- and zinc-district of Wisconsin, ores are now frequently found in so-called clay-openings. These clay-openings, to a considerable extent, represent shaly layers interstratified with the limestone, once containing carbonaceous material. Thus, the inference of the precipitation of the disseminated ores by the carbonaceous material is confirmed.

In the Wisconsin district, iron salts were far more abundant than lead and zinc salts, as is shewn by the very abundant associated iron sulphide. The process of transportation of the iron and precipitation as sulphide is precisely analogous to that of the zinc and lead.

The process above outlined continued for many centuries; perhaps for a geological period or more. By it there were finally locally concentrated along the crevices and disseminated through the limestones and shales adjacent to the crevices considerable quantities of lead and zinc sulphides associated with marcasite. As erosion slowly progressed, the zone of rising and escaping waters slowly migrated from the north-eastern part of the lead- and zinc-district to the south-western part. The circulation within the Galena limestone at a given time is roughly represented by Fig. 14, a north-east to south-west section. The surface of the country is shown by A, B, C, in which A, B, is the cross-section of a north-west and south-east belt, where waters enter, and C is in a parallel belt to the south-west, by which the waters escape.

The numerous curved lines below the Cincinnati shale are intended to represent the general lines of movement of the waters. The widely dispersed downward-moving lateral-moving waters, in the early stages of their journey, were oxidizing and dissolving waters. The upper-moving waters in the trunk-channels (AE) were precipitating waters, and the material was especially likely to be precipitated where the waters came into contact with abundant organic material.

The circulation was much more complex than is shown by Fig. 14. The circulation was not wholly delimited below by the Trenton shale. The water in its underground journey encountered not one crevice, but many crevices; moreover, these crevices were in intersecting sets. The movement of the water would be largely controlled by these fractures, and thus the deflections resulting

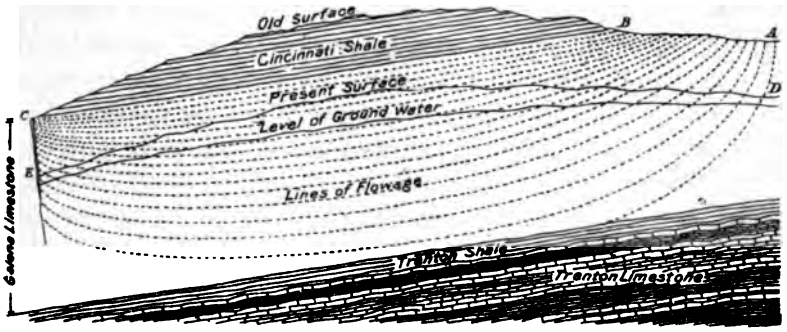


FIG. 14.—THEORETICAL NORTH-EAST TO SOUTH-WEST SECTION OF THE LEAD- AND ZINC-DISTRICT OF WISCONSIN.

from them would be almost indefinitely complex. However, it is believed that Fig. 14 represents the average movement of the water in the Galena limestone. The transference of the ore-material at this time was, indeed, exceedingly complex, but by the combination of all the factors considered the material was precipitated where the water was ascending in and adjacent to the trunk-channels, to a much greater extent than elsewhere. In an early stage of the first concentration by ascending waters, the process took place only in the north-eastern part of the district, for only in that part was the Cincinnati shale cut through and the porous Galena limestone exposed, so that the water was able to escape. From the north-eastern part of the district, the process extended to the south-west, as fast as the shale was here and there cut through by the streams.

By the time that erosion had cut through the Cincinnati shale into the Galena limestone, in the south-western part of the district, and ascending waters were concentrating ores, the north-eastern part of the district may have been a feeding area where waters were descending and where a second concentration was taking place. Therefore, the second concentration by descending waters was probably going on in the north-eastern part of the district at the same time as the first concentration by ascending waters was occurring to the south-west. At the present time, erosion has cut sufficiently deep so that the second concentration by descending waters has extended quite to the Mississippi river; and, indeed, to the west of it. At the present time, the condition of affairs as to the exposures of the formation is represented by Fig. 14 below the line DE, which may be taken as the present surface of erosion.

While it is possible that the vertical order of the minerals is to some small extent due to a first concentration, it is believed that the controlling factor in the regular vertical distribution of the galena, smithsonite, sphalerite and marcasite was the second concentration by the action of descending waters in connection with denudation. The order of the events and the nature of the reactions by which the second concentration took place are substantially like those which form the enriched sulphide ores and the oxidized ores in the Missouri-Kansas district, treated in an earlier part of this paper, and therefore the details of the process need not be repeated.

## VI.—Outlying Districts.

Apart from the four ore-bearing districts of the Ozark region and the Wisconsin-Iowa-Illinois district there are two districts in the Mississippi valley, which yield more or less lead and zinc. These are located in uplifts distinct from the Ozark, though possibly of the same age and genesis.

### A. *South Arkansas District.*

Throughout the Ouachita mountains, which lie to the south of the Ozark uplift and are separated from it by the Arkansas valley, lead and zinc occur. They are associated with silver, gold, antimony, and other metals not found elsewhere in the Mississippi valley. They occur in well defined fissure-veins, associated usually with a quartz-gangue. The ore-bodies show the same evidences of

secondary enrichment as those which may be observed in the Ozark districts. The region is a difficult one in which to do geological work, and so far has not been studied in detail. It would be premature to express any opinion as to the first concentration of these ores.

B. *Illinois-Kentucky District.*

The mines of this district were visited some years ago by Mr. S. F. Emmons,* and have recently been described by Mr. W. E. Burk.† The Illinois-Kentucky district is located mainly in Hardin and Polk counties, Illinois; and in Crittenden, Caldwell, and Livingston counties, Kentucky. Rosiclare, Illinois; and Marion, Crayneville, Fredonia and Crider, Kentucky, are the leading shipping-stations. The ores include both lead and zinc, which occur in intimate association with fluorspar, in small vertical veins or fissures which have very regular courses a little east of north. They are cut by numerous secondary cracks or cross-veins at a somewhat uniform angle. The main fissures can be traced for several miles. Important faults occur in the district. The country-rock is Lower Carboniferous limestone. The hills are capped by fragments of shaly strata belonging to the Coal-measures. At depths not yet reached in mining, the black shale of the Devonian and the underlying Cambro-Silurian dolomites should occur. The rocks of the district have, except locally, only slight dips. In general geology and in the form and shape of the ore-bodies, the district shows close similarity with the others already described. In the association of the ores with fluorspar, the district is at marked variance with the others. On this point, Mr. W. E. Burk may be quoted as follows: —

> Within the vein-walls there is but little country-rock, the filling being firm and fully crystallized. Most of the veins contain a clear transparent fluorspar, giving a snow-white appearance where granulated and shattered. In some veins, perhaps only those containing associated lead- and zinc-ores, the fluorite occurs (especially in open vughs) in well-developed cubical crystals possessing all the various tints through purple, from a pale amethyst to an intense, almost black purple. These crystals represent the last product of crystallization and there is some evidence that this colour is due to traces of certain metals found associated with the zinc and lead; possibly manganese. This presence of coloured fluorite has become a guide to prospectors, for while zinc and lead may not be actually

* "Fluorspar-deposits of Southern Illinois," by Mr. S. F. Emmons, *Transactions of the American Institute of Mining Engineers*, 1893, vol. xxi., pages 31 to 53.

† "The Fluorspar-mines of Western Kentucky and Southern Illinois," by Mr. W. E. Burk, *The Mineral Industry*, 1901, vol. ix., pages 293 to 295.

present, it will usually lead to zinc at some further depth. In fact, there seems to be a sequence in this mineral deposit, and generally the fissures have not been worked deep enough to reach zinc- and lead-ore. This sequence, beginning with transparent or white fluorite, leads to a trace of lead; then comes coloured fluorite with more lead and a trace of zinc. Following this, the fluorite gives place to calcite with more lead and zinc, and zinc predominates with some lead and a mixed fluorite and calcite-gangue. The Columbia mine near Marion, Kentucky, is by far the best known and developed mine operating. This seems to be at the centre of the local upheaval, and has a 6 to 8 feet fissure-vein. The sequence, if taken up at the surface with a showing of violet-coloured fluorite and considerable of zinc carbonate, changes at a little depth to lead and zinc sulphides, the fluorite giving place to calcite. With increased depth, the calcite or calcspar in turn diminishes, with fluorite disappearing almost entirely, and at a depth of 125 feet, the vein is uniformly zinc and lead sulphides from wall to wall, assaying from 30 to 50 per cent. metals. This sequence is in accordance with conditions at other mines in the district.

The Eagle fluorspar-mine near Salem, Kentucky, is now opened in a lower grade zinc-ore with fluorite present to the extent of 50 to 60 per cent., while some other fluorspar-mines in the district are at the point where too much lead and zinc is present for high-grade fluorite and too little lead and zinc as yet for mining operations for these metals. It is probable that all the main fluorite-veins (true faults) will lead at some considerable depth into lead and zinc.*

This association of the minerals, and their vertical sequence, are very suggestive indeed of a first concentration by a deep circulation, modified by a later reconcentration through surface-waters. It has been customary to refer these deposits to fumarole-action, because of the presence of fluorspar. No igneous rocks crop out in the vicinity, and except for the fluorspar, there are no apparent reasons for referring the deposits to different agencies from those at work in other parts of the Mississippi valley. If further studies should show that the deposits are wholly due to the usual genesis, an important addition will be made to the knowledge of the principles controlling the deposition of the ores, in that fluorspar as a necessary evidence of fumarole-action will be excluded. If, on the other hand, fumaroles were an agent in the production of the Illinois-Kentucky ores, these may still be in the main the result of the action of underground waters.

## VII.—General Discussion and Conclusions.

### A. *Immediate Source of the Metals.*

#### 1. Lead and Zinc widespread in Limestones.

Large-quantity analyses by Mr. Robertson of the rocks of the Missouri districts show the presence of minute but important

* "The Fluorspar-mines of Western Kentucky and Southern Illinois," by Mr. W. E. Burk, *The Mineral Industry to the End of 1900*, 1901, vol. ix., pages 294 to 295.

amounts of zinc and lead in the pre-Cambrian, Cambro-Silurian and the Carboniferous.* Analyses by Mr. Weems† show that the Ordovician rocks of the Iowa area also carry minute quantities of these metals. The facts of the field bear out the conclusions drawn from the analyses. It is a matter of common observation throughout the Mississippi valley that the limestones contain minute quantities of various metallic sulphides.‡ Along the western slope of the Appalachians are occasional occurrences of both lead and zinc.

2. Material of Limestones adequate to account for Ore-deposits.

It is therefore clear that the limestones of the Mississippi valley are a source from which the ore-deposits could have been derived. The next question to be considered is whether the residual amounts of these widely dispersed, minute quantities of lead and zinc are sufficient to render it probable that the limestones originally contained an adequate amount of metals to account for the ore-deposits. Upon this point the calculations of Mr. Buell seem to be decisive.

According to Prof. T. C. Chamberlin,§ Mr. Buell has calculated that if the source of the metal in the Potosi area, one of the richest in the Wisconsin district, be restricted to a layer of limestone 100 feet thick, and limited on the outside of the area of paying crevices by half the average distance between the crevices, to account for all the lead which has been taken out, it would only be necessary to suppose that the rock yielded "one fourteenhundredth of one per cent., or a little more than one seven-millionth part of the rocks.‖

In the limestones of many districts, both analyses and observation indicate the presence of more lead and zinc than this; and therefore the amount contained is adequate to account for the ore-deposits.

3. Ores derived from the Cambro-Silurian Limestone.

But, so far as the analyses are concerned, the ore might be derived from any of the limestone-formations of the Mississippi valley

* "Lead- and Zinc-deposits," by Mr. Arthur Winslow, *Missouri Geological Survey*, 1894, vol. vii., pages 479 to 482.

† "Geology of Dubuque County," by Messrs. Samuel Calvin and H. F. Bain, *Annual Report of the Iowa Geological Survey for 1899*, 1900, vol. x., page 567.

‡ Messrs. S. Calvin and H. F. Bain, *cit.*, pages 569 and 570.

§ "Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., page 538.

‖ Prof. T. C. Chamberlin, *cit.*, page 538.

or from the pre-Cambrian rocks; and the next point which needs to be considered is from what source the underground waters actually did derive the metals. This question has already been answered by the full discussion of the circulation of the underground waters in the various districts and the manner of the segregation of the ores. The relations are particularly clear in the Ozark region. The circulation in the formation which contains the most widely-dispersed ores, the Cambro-Silurian, is mainly in that formation and confined between the pre-Cambrian and the Eureka—Kinderhook. It is therefore natural to suppose that the greater quantity of the ore was derived from the Cambro-Silurian; although it is entirely possible that considerable quantities may have been derived from the underlying pre-Cambrian. It has been further seen that, while within the Missouri-Kansas district the main ore-deposits are found in the Carboniferous, the supply for these ore-bodies came from the rocks below, and, therefore, that the source of this material is the same as the deposits in the Cambro-Silurian limestone itself. In other districts of the Mississippi valley, the artesian circulations in the Cambro-Silurian were to a considerable extent limited below by shaly formations at the bottom of the limestone, thus largely confining the circulation to this formation, the limits of ready movement being the shales above and below it. In these cases, it is very probable that the main source of the material is the Cambro-Silurian limestone.

Another argument in favour of the derivation of the ores from the Cambro-Silurian limestone is furnished by the porosity of the Cambro-Silurian as compared with the pre-Cambrian. In order to have filled cavities and produced ore-deposits, the water-circulation must have been active and long-continued.

Water issuing at the surface from mineral springs generally contains not more than 1 part of silica in 100,000.* Therefore, if as much silica be deposited in a cavity as ordinarily issues at the surface, it is necessary to assume when a cavity becomes filled with silica that at least 260,000 times as much water has passed through the cavity as would fill it. The amount of lead and zinc in solution in spring-waters has been very rarely determined. Mr. A. C. Peale† gives the amount of zinc, measured as sulphate, in

* "Lists and Analyses of the Mineral-springs of the United States," by Mr. A. C. Peale, *Bulletin of the United States Geological Survey*, 1886, No. 32, page 235.

† "Mineral-springs of the United States," by Mr. A. C. Peale, *Bulletin of the United States Geological Survey*, 1886, No. 32, pages 49, 59, 62, 64, 65 and 67.

seventeen cases, and as a bicarbonate in one case. In the remaining analyses quoted by Mr. A. C. Peale, zinc is not reported at all, or is given merely as a trace. Therefore, it may be assumed that spring-waters in the lead- and zinc-districts of the Mississippi valley carried somewhat more than the average amounts of these metals. Mr. A. C. Peale's determinations may be accepted as the best approximation towards average conditions available, and the average amount determined as zinc sulphate by him was 0·22 grains per gallon. If all of this be supposed to be precipitated as sulphide, it would require approximately 1,000,000 times as much water to pass through a given cavity as would fill it before the cavity would be closed by precipitation.

Since the metals were present in adequate quantity and the conditions for solution favourable in those rocks through which the bulk of the waters passed, the larger amount of ore was probably derived from them.

Therefore, it is believed that the Cambro-Silurian is the main source of the ore-deposits; although it is recognized that if in the pre-Cambrian rocks lead and zinc were abundant a smaller amount of water passing through these rocks would be the source of a large amount of ore. However, there is little evidence that the pre-Cambrian rocks are richer in lead and zinc than the Cambro-Silurian limestone. Indeed, if one takes the presence of widely dispersed, small quantities of lead and zinc in the two rocks as evidence as to the original amount present, there was probably less in the pre-Cambrian than in the Cambro-Silurian. It therefore appears to us that there is every reason to suppose that the main source of material for the ore-bodies was the Cambro-Silurian limestone.

### B. *Original Deposition of Lead and Zinc in Dolomitic Cambro-Silurian Limestone.*

It has been seen that analyses show the presence of lead and zinc in both the Cambro-Silurian and Carboniferous limestones. The association of lead and zinc with limestones throughout the world is very close and has often been the subject of comment. Limestone, however, has been used to include both magnesian and non-magnesian rocks. In literature, the distinction between the two kinds of rocks has not always been preserved. It is probable

that the association is more common with dolomitic than with non-dolomitic rocks.* If it were possible in every case to determine just what kind of rock is included under the term "limestone," the association of the metals with the magnesian rather than non-magnesian rocks probably would appear much clearer.

Very generally throughout the Mississippi valley, the Cambro-Silurian is so magnesian as to be called the Magnesian series.

In the Mississippi valley, it is certain that there is a very close association of the lead- and zinc-metals with dolomite and magnesian limestone. This is evidenced by the number of profitable districts which occur in this limestone, but in a still more marked way by the sparsely disseminated lead and zinc throughout vast areas of this limestone. Illustrating the general fact of the occurrence of lead and zinc in the magnesian rocks, and ignoring for the moment the productive districts, it may be said that throughout the Niagara of Wisconsin and Iowa, small amounts of galena and blende are found, and in the entire Ozark region small amounts of lead and zinc are found in practically every county where the Cambro-Silurian is exposed. Now turning our attention to the productive districts, in practically every area where ores are mined in the Mississippi valley, dolomite occurs abundantly in intimate mixture with the ores, or in the immediate vicinity of the ore-bodies.

This statement is true even of the Missouri-Kansas district, where there are very large and important ore-bodies in a Carboniferous limestone, which, as a whole, is non-magnesian; but, even here, these ores are associated with dolomitization of the country-rock. This association of the ores of this district with dolomite has been frequently noted. But it has been fully explained,† that the source of the ores and the dolomite alike is the Cambro-Silurian limestone. Therefore this district affords no exception to the rule that the original home of the ores of the Mississippi valley is magnesian limestone.

The reasons which may be assigned for the association of lead and zinc with magnesian limestones are to some extent theoretical. It has been common to consider the association wholly due to secondary causes. Dolomite is a porous rock, and hence is

* "Geology of Dubuque County," by Messrs. Samuel Calvin and H. F. Bain, *Annual Report of the Iowa Geological Survey for 1899*, 1900, vol. x., page 573.

† *Trans. Inst. M.E.*, 1902, vol. xxiii., page 395.

extensively traversed by large volumes of underground waters. Its homogeneity causes it to fracture in extensive planes, and so trunk-channels for circulation are opened through it. It is a rock which may be believed to absorb ores selectively from solutions coming from extraneous sources. It is particularly subject to metasomatic replacement. But none of the explanations which regard as due to secondary introduction the very sparsely disseminated minute quantity of lead and zinc in the magnesian limestone of the Mississippi valley seem to us adequate to explain the facts. It seems to us that the very widespread presence of lead and zinc compounds in magnesian limestone strongly suggests that the original introduction of the lead, zinc and magnesium in the rock was simultaneous. After the three materials had been deposited in the rock the law of mass-action accounts for their common transportation and segregation. The constant association of the three metals leads to the hypothesis that the primary association is due to the fact that the conditions under which large areas of dolomitic limestone formed are favourable to the deposition from the sea of minute quantities of metallic sulphides. This hypothesis has been developed elsewhere,* but will be here outlined.

Many years ago Prof. J. D. Dana showed that complete dolomitization of recent coral-formations has taken place upon the island of Metia. This dolomitization he explains as due to the reaction between the waters of the sea in shallow lagoons and the fine calcareous ooze. He states that "in such lagoons, mainly shut-off from the sea, and therefore in a 'salt-pan' condition, the concentrated brines contained the magnesium chloride and sulphate in a state that favoured the formation of dolomite."† He suggests that dolomite "owes its origin at times if not always" to such conditions.‡

In the Iowa area, the Galena-Trenton formation includes a partly dolomitized series of limestones. Dolomitization extends irregularly from the top downwards and is regional, not being associated with definite cracks and water-channels as in the Car-

* "The Geology of Dubuque County," by Messrs. Samuel Calvin and H. F. Bain, *Annual Report of the Iowa Geological Survey for 1899*, 1900, vol. x., pages 573 to 575.

† *Manual of Geology*, by Prof. Jas. D. Dana, fourth edition, 1895, page 133.

‡ *Ibid.*, page 133.

boniferous Limestone of the Joplin area. The dolomitization occurred very early, seemingly immediately after the limestone was deposited, if not during the deposition. There is evidence that the rocks were formed under shallow-water conditions, but in the portion dolomitized there is no evidence of nearness to shore.

Thus in certain districts the facts correspond to the conditions under which Prof. J. D. Dana has observed dolomitization; and it seems to us probable that the general dolomitization of the Cambro-Silurian limestone of the Mississippi valley took place in large part at least while the limestone was still below the sea by the reactions between the magnesium-solutions in the sea and the deposited calcium carbonate.

Deep-sea dredging has shown that the reduction of various salts to sulphides by organic material is widespread along the sea-bottom. If Prof. J. D. Dana's conclusion as to conditions most favourable to dolomitization be correct, the process is likely to have taken place to more than an average amount where "salt-pan" conditions were approximated. If it be a general fact that lead and zinc occur in large amounts in areas where dolomitization is farthest advanced, as a result of conditions of unusual concentration of the sea-salts, it is a natural suggestion that under these same "salt-pan" conditions the lead and zinc salts were also concentrated. Therefore, where dolomitization is far advanced, there, probably, more than an average amount of sulphides was precipitated by the organic matter.

### C. *Localization of the Ore-deposits.*

In connection with the above, the question naturally arises as to the localization of the ores within definite districts of the Cambro-Silurian limestone, and in small areas within those districts. It has been seen that between the productive districts are great barren regions, and between the productive areas within each district are barren areas smaller than those between the districts, but still large as compared with the highly productive areas.

It seems to us that the localization into districts and areas is largely explained by the peculiar combination of factors which characterize the districts where the ores occur:—(1) They are at places where there has been an early deep artesian circulation between confining shales, and later a surface-circulation; (2) they are at places where the rocks have been fractured by extensive

crevices or faulting, or both; (3) such places are trunk-channels for circulation; and (4) the ores occur at places where reducing agents could be supplied for the precipitation of the ores.

If the ores were somewhat evenly distributed throughout each district, it might be supposed that the limestones of these particular districts was originally richer in lead and zinc than the main areas of Cambro-Silurian limestone; but when it is recalled that within each district there are areas of extraordinary richness separated by many areas of greater size which are almost or quite barren, it is hard to believe that there could have been within a district such sudden variations in the original amount of lead and zinc carried in the limestone. Therefore the explanation of the extreme localization within the district lies mainly in the factors above mentioned, and not in original variation in the amount of material in the limestone.

The same explanation may be applied to the localization into districts, and thus the large barren areas may be explained; but Prof. T. C. Chamberlin doubts whether the unusual facilities for segregation in certain areas is a sufficient cause for the localization of the ores.* He suggests that the localization is due to exceptional original concentration adjacent to lands where the sea-waters may be supposed to have contained more than an average amount of lead and zinc, and in areas of the Cambro-Silurian limestone where eddies or Sargasso seas gathered very large amounts of sea-weed to serve as a reducing agent.† But the fact that the lead and zinc were not concentrated in the Carboniferous Limestone at the time of its deposition at a period during which organic matter must have been more abundant than in Cambro-Silurian time, raises the question whether or not, if there were original concentration in certain districts, it is not adequately explained by unusually favourable chemical conditions for precipitation which were connected with the dolomitization. It has been noted that while there is regional dolomitization in the Cambro-Silurian of the Mississippi valley, the amount of magnesium is very variable. In this connection, the junior author has ascertained that in the Iowa area the productive points are in the areas in which the regional dolomitization is in the most

* The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., page 529.

† Prof. T. C. Chamberlin, cit., pages 529 to 538.

advanced stage; and he offers the suggestion already advanced,* that the same concentration of sea-salts which probably produced dolomitization also resulted in precipitation of more than the usual amount of lead and zinc. However, it remains a very open question as to whether or not in the Cambro-Silurian limestone there was originally an unusual amount of segregation of lead and zinc in the productive districts, as compared with the non-productive barren areas.

### D. *Segregation of Ore-bodies from the Cambro-Silurian Limestone.*

The next general point in the chain of events is the segregation of the ores from the Cambro-Silurian limestone. This subject has been fully treated in the discussion of the various districts. In that discussion it has been assumed that the source of the ore was the Cambro-Silurian limestone, and with that hypothesis the segregation has been traced out. It is here, therefore, necessary only to summarize the main conclusions which have been reached in that discussion.

#### 1. Lithological Succession.

Considering the Mississippi valley lead- and zinc-regions as a whole, disregarding the names of formations, and considering only the lithological succession in each district, we have in descending order:—(1) Thick shale formation; (2) limestone, bearing ore-bodies; (3) shale; (4) limestone, bearing ore-bodies; (5) shale, often interstratified with limestone; (6) sandstone; and (7) pre-Cambrian. In some of these districts, a portion of these formations have been removed by erosion. Excluding the little-known outlying districts, in all of the important districts, except the Missouri-Kansas district, all of the ores occur in the Cambro-Silurian limestone.

#### 2. Vertical Distribution of Ores.

Wherever the full vertical distribution of ores is known, it is essentially the same in each of the districts. Oxidized zinc- and lead-ores with galena occur above and near the level of the ground-water. Below the level of the ground-water are zinc sulphides with subordinate quantities of lead sulphide, and with in-

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 428.

crease of depth iron sulphide increases and locally becomes dominant. In these statements, the ores which occur in the crystalline rocks of Missouri are not considered, and to them the statements as to the vertical distribution are not applicable.

The segregation of the ores is regarded as due to two concentrations. The first circulation was mainly within the limestones between the bounding shales. The water entering the limestone at the surface-outcrops passed down and along the limestone-formations until crevices or faults were found through which it might ascend and escape. At such places, the waters from various sources mingled, some bearing the metallic materials and some bearing reducing agents. The materials were thrown down as sulphides; and so far as can be made out, these sulphides had no regular vertical distribution. As already explained, the sources of the materials for the solutions were the metals in the limestones through which they passed. Thus, the first concentration was accomplished. As denudation continued, the shales overlying the limestones were removed. As soon as water was able to enter at places where there had been a first concentration, a second concentration began. As a consequence of this second concentration, the rich oxidized products were formed above and near the level of the underground-water, and the rich sulphides within a comparatively short distance below the level of the ground-water, as fully explained in the discussion of the individual districts.

## VIII.—Conclusion.

If the general theory above given be correct, there were three stages of concentration of lead and zinc in the Mississippi valley:—(1) A concentration to a minute fraction of 1 per cent. in the Cambro-Silurian limestone at the time of its deposition; (2) a concentration by an artesian circulation early in the erosion-history of the region: and (3) a reconcentration by a shallow circulation in the later stages of the erosion-history.

If this outline be correct, the lead- and zinc-ores in all the districts of the Mississippi valley furnish excellent illustrations of that class of ores produced as a result of a concentration by ascending waters and a later concentration by descending waters. Moreover, all these districts illustrate with remarkable clearness the very important influences of impervious strata in the

development of ore-deposits. Finally, these deposits illustrate beautifully that comparatively shallow circulations may at the point of precipitation deposit ores by ascending waters, and that later such ores may have been reconcentrated by descending waters.

The similarity as to the lithological succession, the occurrence of the ores, and the genetic relations between the ore-deposits and the stratigraphy in widely separated districts in the Mississippi valley seems nothing short of marvellous. Identity seems the only word which fits the case for several of the districts. Whether the above explanation of this similarity be absolutely correct or not, there can be no doubt that the same general explanation is applicable to all the districts. One cannot be explained in independence of the others or in a radically different manner.

If the theory here proposed be compared with those advanced by earlier workers in this region it will be seen to differ from each, and yet to combine features of all. The ascensionists, as typified by Messrs. Percival* and W. P. Jenney,† are followed to the extent that it is believed that ascending waters have been important in the production of the ore-bodies. This is particularly clear in the case of the ores of the Missouri-Kansas district, the one studied in most detail. The ideas advanced differ from those of Messrs. Percival and W. P. Jenney in that these ascending waters are not believed to have been derived from an indefinite and unknown depth, and are not believed to have been heated. They are merely a portion of the general circulation which at the point of deposition has, as a result of the combined action of geological structure and gravitative stress, an upward movement.

We agree with the descensionists, Messrs. J. D. Whitney,‡ T. C. Chamberlin§ and Arthur Winslow,¶ on the fundamental point of deriving the ores from the surrounding rocks. We agree

* Mr. — Percival, *First Annual Report of the Geological Survey of Wisconsin*, 1854, pages 30 to 33; and *Annual Report of the Geological Survey of Wisconsin*, 1856, page 63.

† "Lead- and Zinc-deposits of the Mississippi Valley," by Mr. W. P. Jenney, *Transactions of the American Institute of Mining Engineers*, 1894, vol. xxii. pages 219 to 223.

‡ "Report of the Lead-region of Wisconsin," by Mr. J. D. Whitney, *Geological Survey of Wisconsin*, 1862, vol. i., pages 398 *et seq.*

§ "The Ore-deposits of South-western Wisconsin," by Prof. T. C. Chamberlin, *Geology of Wisconsin*, 1882, vol. iv., pages 544 to 549.

¶ "Lead- and Zinc-deposits," by Mr. Arthur Winslow, *Missouri Geological Survey*, 1894, vol. vii., pages 467 *et seq.*

to some extent with Mr. Arthur Winslow's conception of the residual concentration of the ores, so far as applied to the ores here defined as within the zone of oxidization. We further agree with Mr. J. D. Whitney and Prof. T. C. Chamberlin in the general action of descending waters, but differ in regarding this as following an earlier concentration by a deep circulation.

As to the extent of the application of the theory, we hold that the evidence already collected warrants the belief that the main outlines are certainly applicable to the Missouri-Kansas district, and are very probably applicable to the other districts of the Mississippi valley.

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The PRESIDENT (Mr. J. S. Dixon) moved a vote of thanks to Messrs. C. R. Van Hise and H. Foster Bain for their paper, which formed a most valuable addition to the *Transactions*.

Mr. C. C. LEACH seconded the resolution, which was cordially approved.

Mr. CLARENCE R. CLAGHORN's paper on the "Campbell Coal-washing Table" was read as follows:—

# CAMPBELL COAL-WASHING TABLE.

By CLARENCE R. CLAGHORN.

The Campbell washing-table (the invention of Prof. A. C. Campbell of Asheville, North Carolina, late Professor of Chemistry at Vanderbilt University), owing to its simplicity and efficiency, is rapidly taking a prominent place among coal-washers, and the past two years have seen the erection of a large number of these tables at important plants.

A description of the washer, together with the results of some tests and experiments made during the past year, may be of interest to some of the members. It was described by Dr. W. B. Phillips* several years ago, since which time many important improvements and changes have been made.

The Campbell table utilizes two of Nature's forces, namely, those of gravity and momentum, and it is an adaptation of the familiar bumping-table, with modifications to suit present requirements.

The washer, which is very simple, consists of a shallow rectangular box, A, 9 to 10 feet long by 30 inches wide, swung or suspended at or near its four corners by rods, *b*, *b*, so as to permit of a longitudinal swinging motion of 6 to 8 inches (Fig. 1, Plate XXIII.).

The sides of the washer are formed of oaken boards, *c*, *c*, 1 inch thick, and 12 inches wide at one end and 9 inches wide at the other, with a 2 inches oaken strip or keel, *d*, spaced midway between. These sides and keel joint firmly to a solid head or bumper, *e*, shod with a steel-plate to withstand wear. The bottom is in two parts and has a peculiar curve, the exact figures of which have been found by trial. The lower, or true bottom, is formed of a steel plate, *f*, securely fastened to the side-boards and keel, while above the true bottom is the false bottom, *g* (separated by 1½ inches space), which rests upon two lateral and one central longi-

* *Engineering and Mining Journal*, New York, 1893, vol. lv., page 128.

tudinal filling-strips. This false bottom is formed of galvanized-steel plates (No. 20 gauge), bent to form riffles, and spaced apart from $\frac{1}{16}$ to $\frac{1}{32}$ inch.

The table, or box, is hung by means of the suspension-rods, *b*, *b*, at a slight inclination in the direction of the flow of the wash-water and coal, and this inclination is variable by means of a lever-adjustment at one end, *h*.

The movement of the table is accomplished by means of a peculiar eccentric, *i*, cam-lever, *j*, and connecting rods, *k*. The object is to provide for a slow forward movement ending smoothly, and a more rapid backward swing ending with a jar or bump against the bumping-post, *l*. The designer has admirably accomplished this movement by the novel shape of the eccentric, and the arrangement of the suspended connecting-levers and rods (Fig. 1, Plate XXIII.).

The action of this eccentric or cam, and lever and toggle, may be explained as follows: The lever, *j*, which is suspended by links, *m*, has considerable play between the lever-rocker, *n*, and the adjustable fulcrum-block, *o*. On the forward stroke, the eccentric, *i*, pulls on the lever, *j*, which, turning against the fixed fulcrum, *o*, gives an even movement. The egg-shape of the eccentric or cam gives a smooth change of motion at the full-out point. On the backward or return stroke, the lever turns on the rocker, which is slightly curved, and forms a movable fulcrum for the lever, at the first bearing on the upper end, where the leverage is small and the movement of the table slow. As the stroke proceeds, the fulcrum-point of the lever is lowered, and the movement of the table increases until it reaches its maximum at the moment of impact against the bumping-post, *l*. At this point, the eccentric changes the direction of its motion, while indiarubber-washers, or a spring, *p*, on the connecting-rod, *k*, provides against any undue strain to the lever, *j*, from imperfect adjustment. It can thus be seen how easily the slow forward swing, with the accelerating backward movement and bump, so essential to the table, is accomplished.

The coal to be washed is fed from an overhead supply-bin, through a chute to a sluiceway, which deposits the coal at a point near the middle of the table. The arrangement, providing for the regular feeding of the coal, is both novel and effective. The coal, crushed to the proper size and filling the overhead bin, *q*,

runs down a suitable opening into the sluiceway, *r*, until this sluiceway becomes clogged. Part of the supply of wash-water enters this sluiceway through two jets, *s*, *t*, in the bottom, the flow being regulated by means of the valves shown. When the washer is in full operation, with the feed-water turned on, the water carries the coal into the vertical leg, *u*, whence it falls to the table. As fresh coal is meanwhile running down from the bin, the supply is regular and susceptible of close regulation. Upon reaching the bottom of the vertical sluice, *u*, the coal and wash-water are distributed or spread over the table by means of a sluice-valve, *v*, which is merely a board pivoted to the sides of the sluice, so as to be readily adjusted at the proper angle. Additional supply-water is fed to the table near the head-end, through an iron pipe fitted with a nozzle which distributes the water in a fan-like jet, *w*, over the table.

During the washing process, the coal and the wash-water are discharged over the tail-end into a suitable coal-sluice, *x*, leading to drainage or storage-pits or bins, while the heavy impurities, such as slate, sulphur and bone, are discharged over the head-end into a sluice, *y*, leading to the refuse-bins.

The inclination of the table, the amount of water, the number and length of strokes and jar, all bear important relation to the efficiency of the washer, and may be controlled or adjusted to suit the coal and refuse to be washed.

In operating, the coal and a part of the wash-water are fed upon the moving table, while the main stream of wash-water flows down from the supply-jet, *w*, near the head-end. In flowing over the table, the heavier pieces of sulphur and slate settle quickly to the bottom between the riffles, while the pure coal is washed over the riffles towards the coal discharge-end. So far, the action may be likened to the old sluice-washer with riffles, inasmuch as the flow of water is just sufficient to carry off the light coal and leave the heavy brasses and slate behind. The jarring action of the table, however, not only stirs up the bed of material and keeps it in motion, but gradually works the heavy refuse towards the head-end and into the refuse discharge-hole. Very fine particles of float-sulphur and heavy clay-sludge, which settle in between the riffles, are jarred through the intervening spaces into the cavity between the true and false bottom, and discharged into the refuse-chute at the head-end. The washers work best after being in

operation a few minutes, for then a bed of material from 3 to 4 inches thick has formed at the bottom. At that time, the material near the head-end will be nearly pure refuse, that at the tail-end, pure coal, and that between, variously mixed. A considerable amount of coal, especially the larger and heavier pieces, works toward the head-end from the point of coal-supply, but this coal meets the main water-supply and is washed back.

During experiments to demonstrate the action of the washer, a silver half-dollar was frequently dropped within 6 inches of the tail or coal discharge-end, and invariably after a few minutes the silver piece would appear among the refuse at the head-end.

The Campbell table has a capacity of from 5 to 7 tons of washed coal per hour at an expenditure of about ½ horsepower. The construction-cost is not over £3, but the patent royalty makes it very much more expensive to instal. The sizing of the coal is not important; in fact the table works best on sizes of 1 inch and below. About 1 ton of water, or 250 gallons, is required per ton of coal, and one attendant will readily look after 15 machines. Since the table itself is so inexpensive, the cost of repairs is very small.

About a year ago, when the Lackawanna Iron and Steel Company desired to determine the best type of coal-washer and bye-products coke-oven to use in cleaning and coking Vinton coal, the writer erected an experimental washing-plant. A Campbell washer was used in connection with 8 bye-product beehive coke-ovens (Newton-Chambers type). Considerable raw coal was also forwarded for trial in other washers, and the washed coal shipped for trial in coke-ovens of other types. In all about 5,000 tons of coal were washed in the experimental washing-plant, and a careful series of analyses and weights of products were kept. The results were so favourable to the Campbell washer that the writer is at present installing, at two new collieries now under development, two washeries, each equipped with 56 Campbell tables (112 in all). Each plant is to have a capacity of 2,500 tons per 10 hours.

The coal used for the experimental washer, before referred to, was that which passed through a screen with bars set ¾ inch apart. The proportion of sizes below ¾ inch was as follows:—Through ¾ and over ½ inch, 27 per cent.; through ½ and over $\frac{5}{16}$ inch, 42 per cent.; and through $\frac{5}{16}$ inch, 31 per cent.

The following results were obtained from one test-run of about

1,500 tons, and correspond closely with the results obtained from similar runs:—

| | Pounds. | Per cent. |
|---|---|---|
| Raw coal ... ... | 3,166,024 | 100·0 |
| Washed coal ... ... | 2,970,429 | 93·9 |
| Refuse ... ... ... | 195,595 | 6·1 |

There was 1·47 per cent. of coal in the refuse, and 0·959 per cent. of separable refuse in the washed coal.*

The following analyses were made:—

| | Sulphur. Per cent. | Ash. Per cent. |
|---|---|---|
| Unwashed coal ... ... | 1·910 | 5·810 |
| Washed coal ... ... | 0·857 | 4·800 |
| Reduction by washing ... | 54·607 | 17·500 |

The refuse was analysed as follows:—

| | Per cent. |
|---|---|
| Moisture ... ... ... | 0·400 |
| Volatile matter ... ... | 15·871 |
| Fixed carbon ... ... | 21·081 |
| Phosphoric acid .. ... | 0·035 |
| Sulphur ... ... ... | 17·617 |
| Ash ... ... ... ... | 44·996 |

The separable refuse in the washed coal was analysed as follows:—

| | Per cent. |
|---|---|
| Sulphur ... ... ... | 6·90 |
| Ash ... ... ... ... | 45·40 |

Consequently, the refuse further separable by gravity would only be:—

| | Percentage of Washed Coal. |
|---|---|
| Sulphur ... ... ... | 0·0661 |
| Ash ... ... ... ... | 0·4353 |

The above results indicate the very close separation obtained by the Campbell washer in this test.

In the Vinton coal, the sulphur is contained as pyrite more or less segregated, making separation by gravity comparatively easy; and the proportion of total sulphur disseminated in fine crystals is very small.

In the two washing-plants under construction, the coal from the collieries will, after disintegration in Bradford breakers (in

* These results were obtained by gravity-separation in a saturated solution of calcium chloride.

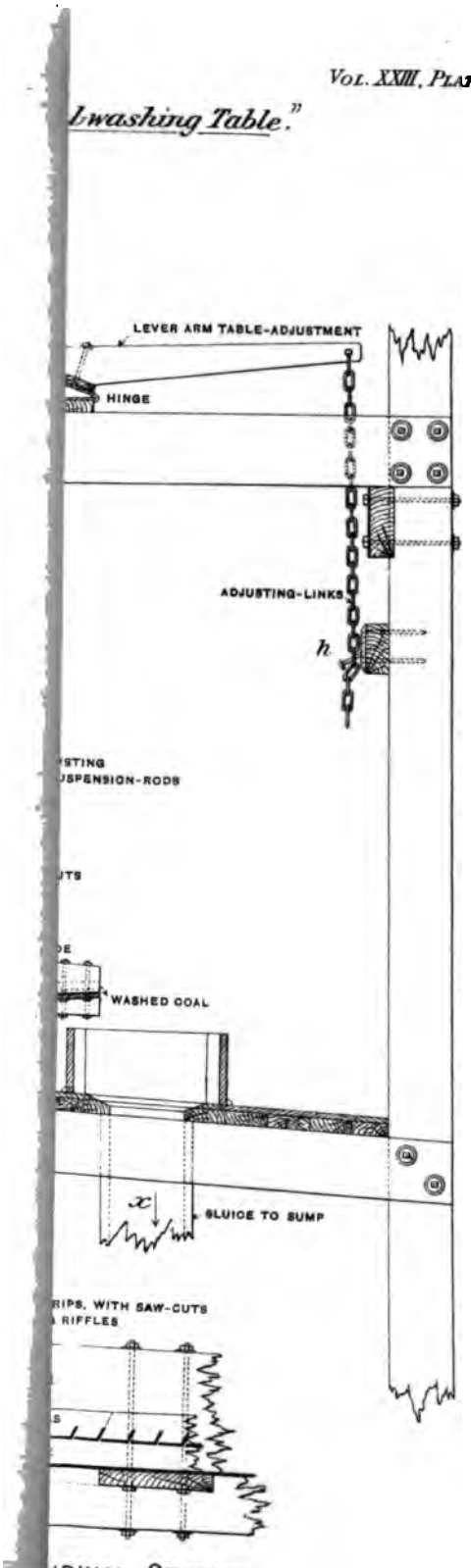
which a partial dry separation will be effected) and crushing in fine rolls, be elevated to the supply-bin over the washers. The refuse will pass, by gravity, from the washer to bins, thence being drawn into railway dumping-trucks for transport to the refuse-heap; while the washed coal from the washers (the main washing-floor being placed high in the building) will be sluiced to large drainage-pits, constructed of masonry and timber, with longitudinal drains at the bottom. In these pits, the coal will be drained, the accumulating bed of coal acting as a filter to catch all sludge, which will thus be disseminated throughout the washed product. After a period of draining, the coal will be loaded into railway-trucks for transportation to the coke-ovens (which are located at the blast-furnaces) by means of 5 tons grab-buckets operated from gantries, spanning the pits. After 72 hours, the only moisture contained in the coal is that held by capillary attraction.

---

Mr. C. R. Claghorn (Wehrum) wrote that the paper referred briefly to two 2,500 tons washing-plants now being installed, and one of these would be in operation by June 15th. By reading "between the lines" the members would note the radical departures from ordinary practice. He would have a distinctly gravity process with but one elevation, that of the finely-crushed dry coal previous to washing; and all elevation of wet coal, and consequent wear-and-tear of elevating machinery, would be avoided. This was a most important point, as he had found that acid water so rapidly attacked elevator-chains and buckets as to be very annoying and expensive.

From the washers, the coal, together with the wash-water, is carried off in sluice-ways, having a fall varying from $\frac{1}{2}$ inch to $\frac{3}{4}$ inch per foot of run, and conducted to the storage-pit, being spilled in a stream of mixed coal and water into this pit, which is built on or in the ground, with paved floor and sides and provided with appropriate drains in the bottom. These drains are perforated on the top by means of slats placed $\frac{1}{2}$ inch apart. In actual operation, there would always be 1 foot or more of coal left on the bottom, forming a filtration-bed, which, of course, constantly increased as the pit was filled. The water filtered downward through the coal-bed and issued as clear as crystal, while all sludge-coal was disseminated throughout the mass of coal and

*washing Table."*




DINAL SECTION
NG RIFFLES, &c.

was not gathered in one mass, as was the case with sludge-tanks or settling-pools. For regularity in coke-product, this was an important point, for sludge by itself did not make exactly the same coke-product as the ordinary run of coal. In this way, he entirely avoided the use of overhead bins, which would be high in first cost, and the expense of their maintenance would be considerable.

In his case, he used one long pit formed by excavating in the ground, and the bottom and sides were paved with stone. This bin was divided into three parts by cross bulk-heads, and while he was washing into one, another was draining, and a third was being loaded out. On account of the climatic conditions of the country, the pit was covered by a building, having sides and roof, so that it might be heated slightly in winter, and to prevent rain and snow from falling into the pit and the wet coal from freezing.

By this system of sluicing, the coal packed very hard, it would not run through ordinary gates in the bottom of bins; and as the pit was formed in the ground, the drained washed coal was reloaded by means of grab-buckets, electrically driven, operating on gantries which spanned the pit and the reloading tracks. These buckets had a capacity at one grab of 5 tons, and as each gantry had an ultimate capacity of 1,500 tons daily two gantries were necessary for an output of 2,500 tons at each plant.

He had repeatedly been asked whether the bottom drains in the pit would not fill and clog, but this was not the case, because the water came to them clear. At first, when the coal filter-bed was thin, some coal would find its way into them, but their slope was such that the water sluiced it away at once, and this loss, which occurred only when starting a freshly cleaned pit, was very inconsiderable.

As only clear water is wasted, there was no chance for damage-suits, by landowners having riparian rights below their works on the waterway. He had spoken but briefly on these points in his paper, as he hoped in the near future to write a more elaborate and detailed description of these matters, and to furnish figures obtained from extended runs of the present plant.

Prof. R. A. S. Redmayne (Birmingham) inquired as to the percentage of dirt contained in the coal previous to washing. A little over 6·1 per cent. of refuse was said to be washed out, but most washers claimed the same results from similar coal. A

new coal-separator and washer with very good results was erected at the Zollern pits, near Dortmund, in 1890 or 1891, and it was specified that the washed coal should not contain more than 6 per cent. of refuse. After working a year with raw coal containing 13 per cent. of refuse, the average result was found to be 5·6 per cent. of refuse, while the amount of coal lost in the dirt was very small. It seemed to him that, as the principle of washing was the rate at which the coals would fall through water—an element common to all—the results would naturally be about the same in all good coal-washers.

Prof. Henry Louis (Newcastle-upon-Tyne) did not think the claim of the novelty for the feeder described was altogether justified. Unless he was mistaken there was a machine for gold-amalgamation brought out about 40 years ago, that used the same type of feeder for feeding the material on to the separating table. It would be interesting to know on what the writer based his statement that sizing was of no particular use with this table. It was one of a number of tables of somewhat similar type coming into favour at present, and in all of them sizing was found to be of some use, and probably better results would have been shown with this washer if some method of sizing had been adopted. The coal contained about 7 per cent. of refuse, and of this practically 1 per cent. of refuse was left; this was by no means close saving—six-sevenths of the heavy separated from the light was not particularly good work, especially as the material was a good one to work with.

Mr. T. E. Forster (Newcastle-upon-Tyne) said that they would not consider coal containing only 6 to 7 per cent. of refuse as particularly dirty, as they were used to washing samples containing 20 to 25 per cent. He asked what this table would do with such coal: if not more than 1 per cent. was left, and if 24 per cent. were taken out, the result was much better than this table appeared to give with this particular coal.

Mr. T. H. C. Homersham (Bradford) stated that at the colliery mentioned in the paper, the coal was made into coke, and that might affect the question of sizing.

Mr. C. C. Leach (Seghill) said that the necessity for sizing the coal was to get it clean; and it did not matter what it was wanted for afterwards.

Mr. C. BURNETT (Durham) wrote that the Campbell coal-washing table bore a striking resemblance to the Craig washer,* both being of the jigger type, the jigger or washing-tray being suspended at each end and provided with means for adjusting the inclination of the tray to suit the particular variety of coal to be treated. The coal, on its delivery to the washing-tray, being partially floated, was carried forward by the water; while the impurities, owing to their greater density fell to the bottom of the tray, and were by the quick return and bumping of the trough against the stops, jerked backward up the easy slope of the tray, and finally delivered on to a refuse-chute: the coal, as already explained, passing off at the lower end of the tray into a suitable receptacle. Careful adjustment of the number and length of stroke, as explained by Mr. Claghorn, was necessary to ensure its best working conditions, while the output per machine was very limited. From a careful inspection of the drawing accompanying the paper, he failed to see how the plant could be produced for £3 as stated. He would not expect the plans to pass through the drawing office at this amount, and he concluded that the sum stated in the paper was a clerical error.

He noted that for washing 500 tons per hour, 112 tables were required: this quantity could be treated by 10 washers of the Murton type;† but the continuous trough-washer in a test against a washer similar to the Campbell proved its great superiority over those of the jigging type, while no other adjustment than the mere regulation of coal and water to the trough, was necessary.

The following analyses of coke from unwashed coal and coke treated by the jigger and endless trough-washers respectively show conclusively the superiority of the endless trough over the jigger.

| | Coke from Unwashed Coal. | Coke from Washed Coal. Jigger Washer. | Coke from Washed Coal. Murton Washer. |
|---|---|---|---|
| Carbon ... ... | 89·21 | 90·55 | 92·06 |
| Sulphur ... ... | 1·93 | 1·78 | 1·65 |
| Ash ... ... ... | 8·73 | 7·50 | 6·10 |
| Moisture .. ... | 0·13 | 0·17 | 0·19 |

The PRESIDENT (Mr. J. S. Dixon) said that he had laid some stress on this question of sizing in his address, because it was found in their washers to be essential for good results. The washer de-

* *Trans. Inst. M. E.*, 1902, vol. xxiii., page 179.

† *Ibid.*, 1895, vol. ix., page 42.

scribed seemed to be a cheap one, compared with those in use in Scotland, on which thousands of pounds had been spent. He had pleasure in proposing a vote of thanks to Mr. Claghorn for his interesting paper.

Mr. T. E. FORSTER seconded the resolution, which was cordially approved.

Mr. C. R. CLAGHORN (Wehrum, Indiana County, Pennyslvania, U.S.A.) wrote that, except taking the results of analyses, no attempt had been made to obtain the average amount of separable dirt contained in the raw coal. From the figures given this would appear to be roughly about 6·61 per cent. In any commercial process, there was always a waste of product which appeared to be unavoidable and was to be expected. The amount of coal wasted or lost in the refuse in the test given, namely, 1·47 per cent., was as low, if not lower, than had been obtained with our coal in any of the other washers experimented with, namely, trough, Robinson and jig types. In the case of the Campbell washer and others of the same type, the principle was not alone that of the rate of fall through water. It was intended that a harmonious combination of the forces of gravity and momentum should be affected. Thus, there was the trough-principle of the floating-off of the light coal, while the heavier refuse was retained on the rough bottom, while the momentum given by the jarring action gradually worked the heavy refuse toward the head-end.

Since writing his paper, he had read Mr. Scott's description of the Craig washer,* and found that the Campbell and Craig washers were almost identical in principle.

In this country, the term jig-washer was only applied to washers of the Harz type having pulsating water-supply. Jig-washers are certainly very efficient, but require close sizing, and therefore a plant of jig-washers carries with it a correspondingly complete equipment of sizing screens.

In speaking of sizing, he (Mr. Claghorn) should have stated that close sizing was not important. As a matter of fact, previous to any complete coal-washing process, the coal must first be crushed or disentegrated in order to disassociate or free the coal from the particles of refuse; and, on general principles, it might be con-

* *Trans. Inst. M.E.*, 1902, vol. xxiii., page 179.

cluded that the finer this disintegration, the greater the opportunity for mechanical separation. The Campbell table, however, seemed to work best after a bed of coal had formed on the riffles, the fine coal filling the interstices of the larger pieces; and therefore, close sizing was not necessary. He did not mean to state that a preliminary crushing of the raw product was unnecessary. It was quite probable that some of the 1·47 per cent. of coal lost was attached to or included within pieces of slate or sulphur, and a finer disentegration might produce more favourable results. In the test referred to, it would be noted that the coal used was screenings and no means was at hand for further crushing.

He (Mr. Claghorn) could not state what the washer would do with coal containing from 20 to 25 per cent. of refuse, as no one would attempt to mine so impure a coal in the United States at the present time. He had no doubt, however, that the washer would effect as close a separation as in the test given.

As to the cost of the washer, the cost of the drawings, patterns and templates once made, answer for any number of washers and the more washers constructed from these designs, the less the *pro rata* cost. The actual cost of construction, including wood and iron work and labour would hardly exceed the figures named. In this connection, he referred only to the washer proper and not to the building and machinery contained therein.

Mr. Scott's paper on the Craig washer referred to, contains such a lucid description of the operation of percussion-washers, and answers to some of the questions might be found by reference to it.

Almost all coal-washers, separated coal from slate and seggregated sulphur; and on account of the great difference in specific gravity, this was a fairly easy proposition. Clay-sludge and float sulphur (disseminated in minute pyrite crystals) were much more difficult to remove and many coals carry their impurities in these forms.

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Dr. W. L. Goodwin's paper on "The Mining, Concentration and Analysis of Corundum in Ontario, Canada" was read as follows:—

# THE MINING, CONCENTRATION AND ANALYSIS OF CORUNDUM IN ONTARIO, CANADA.

By W. L. GOODWIN.

In 1896, Mr. W. F. Ferrier, then of the Canadian Geological Survey, bought a number of crystallized minerals, some specimens of which were labelled "Pyroxene from Carlow." He recognised them as corundum, and traced the specimens to their source in Carlow township, Renfrew county, Ontario. He collected there a considerable quantity of the mineral for the Geological Survey Museum.

There the matter rested, until the Ontario Government employed Prof. W. G. Miller of the School of Mining, Kingston, to make a geological examination of the district with the view of ascertaining the extent and possible commercial value of the deposit. During the summers of 1897 and 1898, Prof. Miller and his assistants showed the existence of corundum over an area of 30 by 150 miles, stretching from south-west to north-east across the counties of Haliburton, Hastings and Renfrew, with smaller patches in Peterborough, Lanark and Frontenac counties (Fig. 1). Boulders containing corundum, and the characteristic rock in place, have been found in other parts of Ontario, and in the province of Quebec. It would seem then that the mineral is very widespread in its occurrence in this part of the world. But, so far, it has been found most richly in the northern parts of Hastings and Renfrew, where it occurs as a primary constituent of varieties of syenite, described by Mr. Miller* as follows: "Numerous varieties of syenite are met with in this field, both as regards size of grain and constituent minerals. In some cases, the rock consists almost entirely of acidic feldspar, pink or white in colour. In other cases, nepheline, mica, hornblende or corundum is present." These syenites occur as more or less well-defined dykes cutting through the gneisses, but in some cases the two rocks merge gradually. In the counties of Frontenac and Lanark, the corundum is found in a basic anorthosite, an occurrence similar to those in Russia and India. A typical specimen of syenite from

* *Report of the Bureau of Mines*, vol. viii., part ii., page 206.

the Blue Mountains, Peterborough county, shows the following composition, that of nepheline-syenite:—†

| | |
|---|---|
| Silica, $SiO_2$ ... ... ... ... ... ... | 58·27 |
| Alumina, $Al_2O_3$ ... ... ... ... ... | 23·75 |
| Ferric oxide, $Fe_2O_3$* ... ... ... ... | 1·86 |
| Magnesia, MgO ... ... ... ... ... | trace |
| Lime, CaO ... ... ... ... ... ... | 1·89 |
| Potash, $K_2O$ ... ... ... ... ... | 5·17 |
| Soda, $Na_2O$ ... ... ... ... ... | 6·90 |
| Loss on ignition ... ... .. ... ... | 2·30 |
| Total ... ... ... ... | 100·14 |

* Ferrous oxide, FeO, is estimated as ferric oxide, $Fe_2O_3$.

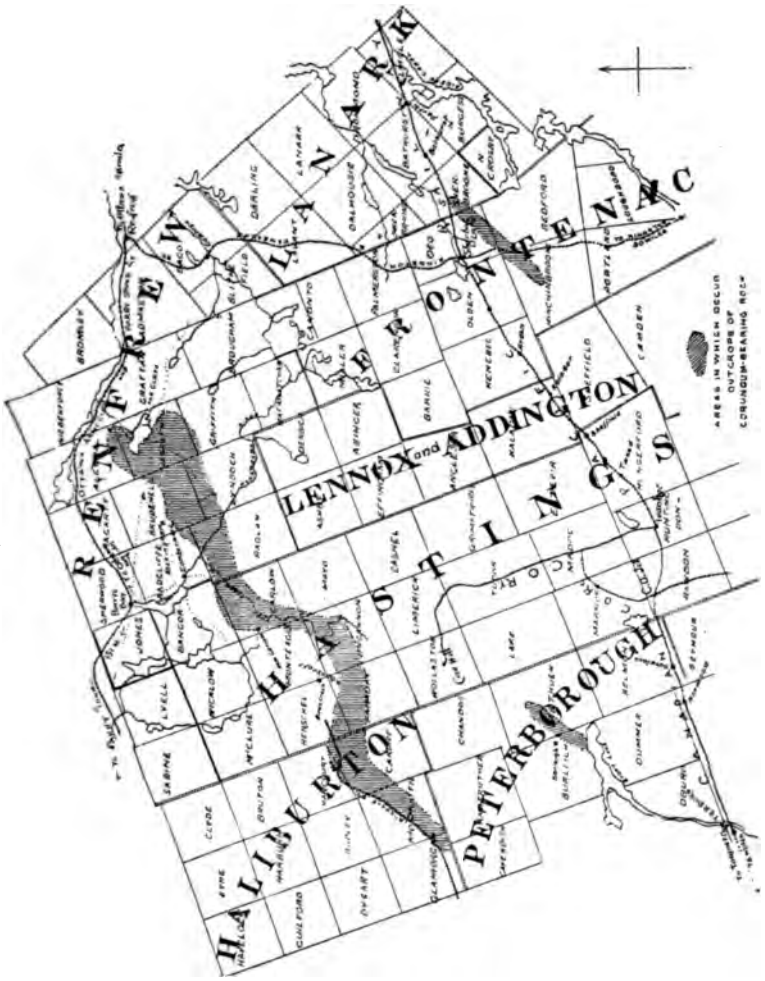


FIG. 11.—INDEX-MAP OF CORUNDUM DISTRICT. SCALE, 26 MILES TO 1 INCH.

† Prof. W. G. Miller, *loc. cit.*, page 207.

This is a region of peculiar interest, not only to geologists but also to mineralogists. Sodalite is found in considerable masses in the western part of the corundum-belt. In the north-east (Lyndoch township) are found large crystals of beryl and a mineral of the columbite series containing a small percentage of tin. The cerite-earths have been identified by the writer in the corundum-concentrates, and, doubtless, a more extended and minute investigation of the region will reveal places where these interesting substances are concentrated in quantity. The exploration has so far been made by geologists; and the rapidity and precision of their work, covering a territory of 150 by about 30 miles in two seasons of about three months each, form a good demonstration of the superiority of this over the old rule-of-thumb method of prospecting. Numerous discoveries of corundum were made, and, in some cases, very promising outcrops were discovered.

In the autumn of 1897, a considerable quantity of the corundum-rock was taken from several of the best outcrops and investigated in the laboratories of the Kingston School of Mining. Concentration by jigs on the large scale was found by Prof. De Kalb to be easy, but was somewhat complicated by the presence of a small percentage of magnetite. This was successfully removed by a Wetherill magnetic separator, leaving a remarkably pure product, amounting to from 12 to 15 per cent. of the rock. The outlook was now so promising that the Ontario Government found no difficulty in securing the development of the corundum-deposits by a strong company, to which certain rights of choice were given, on condition that the development should proceed apace. This company, finally organized as the Canada Corundum Company, selected the Robillard property near the Madawaska river, North Renfrew county, for immediate development. The outcrop is here on the southern face of one of the rugged hills characteristic of the corundum-area. The mineral is embedded in pink felspar, with smaller quantities of mica, and a little magnetite.

The rock is removed by open mining, the situation being unusually favourable for this method. Two benches are worked, and an enormous quantity of corundum-rock is now in sight between them. The benches are being carried back over a breadth of about 30 feet. Drilling was done by hand when the writer visited the deposits a year ago; but, as most of the blasting broke off large bodies of rock from the face of the quarry, the rock was got out at a very rapid rate. The following account of the con-

centration has been kindly prepared for the writer by Mr. M. F. Fairlie, B.Sc., who acted as foreman of the mill last summer:—

After a rough hand-picking at the mine, the ore is transported by wagon to ore-bins at the mill. From the ore-bins it is fed by hand into a No. 2 Gates gyratory crusher, with a rated capacity of 12 tons per hour, which, by the way, is a figure far in excess of its actual accomplishments on corundum-ore.

FIG. 2.—CORUNDUM-ROCK.

The ore, which can now pass through a 2 inches ring, is elevated into a storage-bin, whence it is fed by automatic roller-feed into a set of 16 inches by 24 inches Gates economic rolls. This and subsequent crushing is done wet.

From these rolls it is raised by elevator to a quadruple-compartment, straight trommel. The first two compartments of this trommel are fitted with 12 meshes punched-steel screens, and the second two with 4 meshes screens.

The products from the first two compartments are run by gravity to the second trommel.

The product from the third and fourth compartments passes to a double-compartment Hartz jig fitted with 8 meshes screens.

The overflow from the first trommel passes to a double-compartment Hartz jig with 4 meshes screens.

From the first-mentioned Hartz jig, the concentrates and hutch work go to a set of 30 inches by 6 inches high-speed Colorado rolls; and the overflow goes out as waste-tailings.

From the second Hartz jig, the hutch-product passes to the third trommel. The overflow goes back to the Gates rolls and again to the first trommel

The product from the first compartment of the first trommel passes, as before-mentioned, to the second trommel, which divides it into two sizes going to two double-compartment Gates high-speed jigs.

The hutch-product from these jigs goes to the third trommel, the concentrates to Colorado rolls; the tailings are waste.

The products which go to the Colorado rolls are crushed and elevated to the third trommel fitted with 12 meshes punched-steel screens. The overflow returns to the rolls; what passes through goes to a V-shaped hydraulic classifier, merely to remove excess of water, and thence to the concentrators, and Bartlett and Wilfley tables.

The tailings from these tables are waste; the concentrates are dried in a steam-drier, heated by exhaust-steam from the engine.

After a perfect drying, the corundum is elevated to a storage-bin. Thence it is run through a magnetic separator, the electricity for the electro-magnet being supplied by a dynamo which also supplies light for the mill and offices.

The magnetite, having been thus removed, the corundum is elevated to *splitters*, which are straight screens having a reciprocating motion produced by an eccentric.

These splitters sort the corundum-product into four sizes:—(1) Fines from 90 meshes upward; (2) 80 meshes; (3) 30 meshes up to 70 meshes; and (4) oversize. Nos. 1, 3 and 4 sizes go to "grades" of the same pattern as the splitters. The grades divide No. 1 size into sizes 90-100-120-150-174-200. No. 3 size is divided into sizes 30-36-46-54-60-70. No. 4 size is divided into sizes 12-14-16-20-24. The oversize from No. 4 size is returned to the Colorado rolls to be recrushed.

As purity of product is essential, and as it has been found impossible to secure a pure product in the sizes from 30 up to 200 meshes, by the process outlined above, it has been found necessary to rewash the sized product. Rewashing without sizing was tried, but was found worse than useless. So, each size is rewashed separately on a Wilfley table, used for this purpose alone, where practically every trace of felspar is removed. As a small percentage of magnetite still remains, especially in the finer sizes, the product is again dried and run through the magnetic separator and graders. The product after sizing is now ready for shipment.

A Hooper pneumatic jig has been installed, for the purpose of experimenting on the dry sized corundum. However, its application is limited, owing to the fact that the air-blast is not sufficient for sizes finer than 100 meshes; and "blows through" sizes coarser than 24 meshes, without concentrating them. Intermediate sizes, however, it will clean well, with the advantage that drying and regrading is done away with.

Power for the mill is supplied by water and steam.

A five-nozzle, hurdy-gurdy type, Leffel water-wheel is used to supply power for the crusher and rolls, the power being transmitted by cable-transmission.

The power required for the remaining machines is supplied by a 35 horsepower high-speed Bell engine, the exhaust-steam being used for the steam-drier and for heating the mill. Steam is supplied by a 35 horsepower boiler, of locomotive type.

Water is pumped from a penstock to a tank situated above the crusher, by a steam-driven duplex pump and by a belt-driven triplex pump.

This plant, hardly more than experimental in size, is now turning out about 3 tons of corundum-concentrates a day. The amount of fines is proportionately small, a favourable circumstance not

FIG. 3.—WATER-POWER.

usually present in such cases. The products are put up in sacks of 100 pounds each, and carried by steamer to Barry bay on the Canada Atlantic railway, a distance of 20 miles from the mine. This route will soon be superseded by a new line of railway (Irondale, Bancroft and Ottawa) running close by the camp and connecting it with both rail and water-transit to the outer world. Labour is plentiful, wages are moderate (from 4s. to 8s. per day), and supplies cheap. The men are boarded well at a little over 1s. 6d. a day.

It is worth noting that water-power is abundant in the corundum-region, and that with the development of mining and concentrating it will be possible to meet amply the demands for power. This is of the greatest importance in a district so far from the coal-fields. It is true that wood is still plentiful and fairly cheap (about 5s. a cord), but it cannot be depended upon as a permanent source of power.

In connection with the investigation of Ontario corundum, it was found necessary to devise methods for determining rapidly and with sufficient accuracy the percentage of corundum in the rock and in the various concentrates. An account of the methods adopted was given by the writer in a paper read at a meeting of the Canadian Mining Institute in 1901,* but a summary may be found interesting here. There are peculiar difficulties in the determination of corundum, owing to the presence of combined alumina in the gangue. This precludes the determination of the corundum by any method of fusion and dissolution which would bring the corundum itself into solution. The analyst is confined to physical methods, and to those chemical methods which are based upon the solution of the gangue, leaving the corundum undissolved. When it is remembered that the gangue consists of such minerals as felspar and mica, it will be seen at once that the most practicable solvent is hydrofluoric acid, in which crystallized alumina is practically insoluble when certain precautions are taken. If the temperature is not allowed to rise above 100° Cent. the corundum is attacked very slowly, while the other minerals are brought into solution at once. The finely-ground sample is treated in a platinum-crucible with a few drops of sulphuric acid and a sufficient quantity of hydrofluoric acid. It is then evaporated on a steam-bath, until the hydrofluoric acid ceases to come off. The crucible is heated over a Bunsen burner until fumes of sulphuric acid appear, and the contents are then washed on to a filter, washed, ignited and weighed. The preparation of the sample for analysis is somewhat difficult. Thorough and repeated crushings in a diamond mortar, while adding a little iron, have the advantage of rapidity and the production of a large sample. The only alternative seems to be grinding a small weighed sample in an agate-mortar, but in this case it is very difficult to prevent loss. The mortar may be covered by a sheet of paper with a small

* *Journal of the Canadian Mining Institute*, 1901, vol. iv., page 180.

hole for the pestle. Then, by setting the mortar on a sheet of dark paper, it is possible to recover any small grains which jump out. This method of preparing the sample was adopted especially for the determination of iron in the corundum. For this analysis the finely-ground sample was brought into solution by fusion with sodium bisulphate, as recommended by Prof. Lawrence Smith. Silica was determined from samples prepared in the same way, the gain in weight being taken as silica derived from the mortar.

As the greater part of the gangue of the Ontario corundum-deposit now being worked consists of felspar, a second method of determining the percentage of corundum presents itself in the specific gravity of the mixture. This method was used extensively during the investigation of concentration - processes by Prof. De Kalb, and the results were found to agree with the chemical process closely enough for milling purposes. The method is very rapid, but obviously could not be applied indiscriminately to corundum-rock and concentrates, without at least an approximate knowledge of the specific gravity of the gangue. Still, in following the work of a concentrat-

FIG. 4.—CRAIG-MINE MOUNTAIN, RENFREW COUNTY.

ing-plant running continuously on a fairly uniform rock, the method could be relied upon to show the efficiency of the plant.

Determinations by mechanical separation with heavy solution were also tried. These gave higher results than the methods already mentioned, due to the adherence of a small quantity of felspar and mica to the corundum-grains. A sample of high-grade grain corundum gave, by the three methods, the following percentages of corundum:—

| | |
|---|---|
| Chemical analysis ... ... ... ... | 93·68 |
| Specific gravity ... ... ... ... | 93·71 |
| Heavy solution ... ... .. ... | 95·23 |

By the use of modern concentrating-machinery and the adoption of a process founded on scientific study, Ontario corundum has been brought to a degree of purity hitherto unknown. The writer some time ago analysed a mill-sample of grain-corundum with the following results:—

| | |
|---|---|
| Corundum ... ... ... . ... | 95·64 |
| Silica ... ... ... ... .. ... | 0·87 |
| Iron ... ... ... ... ... ... | 0·80 |
| Water in pure corundum ... .. | 1·22 |
| Total ... ... ... ... | 98·53 |

This is an average sample of the commercial product, taken more than a year ago, and before the plant was in its present good running order.

As there are numerous deposits in addition to that which is now being worked at Craigmont, Ontario corundum bids fair to play an important part among abrasives. Its good qualities as an abrasive have been proved in a variety of ways. Prof. Lawrence Smith has shown that the hardness of corundum is inversely proportional to the percentage of combined water. The writer's analyses show that Ontario corundum contains on the average about 1·2 per cent. of water. According to the analyses of Prof. Lawrence Smith, the percentage of water in corundum varies from 0·68 to 3·10 per cent., Asia Minor corundum carrying 1·60 per cent. The percentage in emery varies from 1·90 to 5·62, Naxos emery containing 4·72 per cent.

Made into wheels and tested in a practical way, its superiority to the less pure varieties has been proved, its cutting and wearing qualities, dependent upon crystalline cleavage, being better than those artificial substances the crystals of which possess no cleavage.

The cleavage of Ontario corundum is well marked. Parting planes are also present, and the good qualities dependent on cleavage were found in the case of one deposit to be somewhat impaired by these planes, which caused the cleavage-pieces to be long and splintery. This characteristic is, however, absent from the better deposits.

FIG. 5.—QUARRY ON CRAIG-MINE MOUNTAIN.

The X-ray photography has been used by Prof. Miller to distinguish pure corundum from mixtures of corundum with garnet and other siliceous impurities. Aluminium and its oxide are permeable to the X-rays, while the silicates commonly found mixed with corundum are opaque. This affords a quick and certain method of testing the purity of grain-corundum.

Prof. R. A. S. REDMAYNE proposed a vote of thanks to Dr. W. L. Goodwin for his interesting paper.

Mr. S. F. WALKER seconded the resolution, which was cordially approved.

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Mr. CARLOS A. LYNES HOSKOLD's paper on "Deposits of Hydroborate of Lime: its Exploitation and Refination" was read as follows: —

# DEPOSITS OF HYDROBORATE OF LIME: ITS EXPLOITATION AND REFINATION.

By CARLOS A. LYNES HOSKOLD.

## 1. Introduction.

The industry connected with the exploitation and refination of mineral substances containing boric acid in payable quantities has received considerable attention in the commercial world. Taking into consideration the various uses to which the refined product is applied in various manufacturing and other processes, no doubt these will be further extended; and consequently it is rational to expect that its importance will continue to increase, giving a greater impulse to and necessity for the discovery of new fields capable of yielding a larger and more constant supply of this class of mineral, as also the discovery of a more economical mode of refining the crude mineral containing boric acid.

Apart from a few scattered notices devoted more especially to the theory of the origin of the elements forming boric acid, as a chemical combination with other mineral substances, and as refers to locality of occurrence, not much information of a practical character in reference to the cost of production and refination, of value, has as yet appeared in English or foreign literature known to the writer. In fact, it is natural to infer that producers and refiners are extremely loth to supply detailed information as to the precise cost of working crude hydroborate of lime and other minerals containing boric acid, and that due to refining.

Mineral substances containing boric acid have long since been noted as occurring in various parts of the world, curiously so in Italy, and more recently in California, Turkey and South America.

## 2. Argentine Republic.

The occurrence of deposits of borate of lime has been recognized in the Argentine, Chilian, Bolivian and Peruvian republics, and in some of these countries it has been worked to a considerable

extent. Our remarks, however, will chiefly be confined to the Argentine, in the northern part of which various borate-of-lime-mines exist. The deposits of this class of mineral are distributed throughout the northern provinces, that is, Salta and Jujuy, where working has been carried on upon a comparatively small scale; but considering the great distance from the mines to a railway-station, the high cost of transport to the railway and thence to the nearest sea-port, and the cost of freight to Europe, not much profit has accrued.

*National Territory of the Andes.*—The large area of land situated in the north-western part of the republic, over which Chile claimed control, but which now forms part of the Argentine republic, and is termed the "National Territory of the Andes," also contains various important deposits of hydroborate of lime of good quality. This large area of land is bounded to the north by Bolivia, to the east by the provinces of Salta and Jujuy, to the south by the province of Catamarca and to the west by Chile. It is, as stated, a new national territory, and passed into the possession of the Argentine Government by arbitration in 1899.

The deposits of borate of lime are found in districts at a considerable distance one from the other; the thickness of the deposits is not regular, and they vary from a few inches up to 3 feet, and sometimes the most inferior parts are mixed with débris. It is also curious to note that some portions of the deposits of mineral form the present surface; but, more frequently, the borate-of-lime-deposits are covered by surface-soil of variable thickness.

Recently, applications for about 200 concessions of borate of lime in the National Territory of the Andes have been received in the National Offices of Mines and Geology.

The principal districts in which the borate of lime occurs are those of Caurchari, Antuco, Partos Grandes, Hombre Muerto, Ratones and Diablillos. The first is situated at a distance of 180 miles from the railway at Salta, the second at 144 miles and the third at 189 miles respectively. The altitude of these regions varies from 18,000 to 18,500 feet above sea-level, and the mule-tracks leading to them pass over sterile plateaux, precipitous mountain-ridges and deep, difficult and dangerous gorges. The whole distance to the railway-station at Salta occupies 6 or 7 days with loaded mules.

The cost of transporting borate of lime from the mines in these regions to the railway-station, near Salta, has been variously estimated, as it depends to a great extent upon the number of mules available when required and the caprice and exactions of the owners. However, in a general way, it may be reckoned at the rate of 8 paper dollars per mule-load of 12 arrobas of 25 pounds each or, say, a total weight of 300 pounds. Then, for the number of mules required to transport 1 ton of mineral, we have (2,240 ÷ 300 = ) 7·46 mules or, say, 8 mules.

The following calculation has been based upon the present value of labour and means of mule-transport, and is believed to be a close approximation to the actual cost of extracting the borate-of-lime mineral from the districts named, and placing it on the English market.

| | Cost per Ton. | | | |
|---|---|---|---|---|
| | Dollars. | £ | s. | d.* |
| Extracting and drying borate of lime ... ... | 5·50 | 0 | 9 | 5 |
| Cost of bags for transporting mineral ... ... | 6·50 | 0 | 11 | 2 |
| Transporting mineral to railway-station ... ... | 58·50 | 5 | 0 | 1 |
| Transport from railway-station near Salta to the port of Colastine on the river Parana .. | 14·10 | 1 | 4 | 1 |
| Transferring mineral from truck to steamer ... | 1·00 | 0 | 1 | 8 |
| Total cost on ship-board ... ... ... | $85·60 | £7 | 6 | 5 |
| Transport from port to Liverpool ... ... ... | 11·70 | 1 | 0 | 0 |
| Transferring mineral from ship to warehouse, insurance and commissions, say ... ... | 0·86 | 0 | 1 | 6 |
| Total cost of putting mineral into England | $98·16 | £8 | 7 | 11 |

* This is reckoned by taking the exchange of gold of the day at 2·32 dollars and 5·04 gold dollars as equivalent to one sovereign.

The borate-of-lime mineral differs in quality on account of its being mixed with foreign elements; but when comparatively free from such substances, an official analysis gave the following results:—

| | Per cent. |
|---|---|
| Boric acid ... ... ... ... ... ... | 39·53 |
| Hydrochloric acid ... ... ... ... ... | 0·46 |
| Sulphuric acid ... ... ... ... ... | 0·26 |
| Carbon dioxide ... ... ... ... ... | 0·02 |
| Carbon monoxide ... ... ... ... ... | 7·38 |
| Magnesia ... ... ... ... ... .. | 0·32 |
| Lime ... ... ... ... ... ... | 12·81 |
| Oxide of iron ... ... ... ... ... | 0·39 |
| Sand and earth ... ... ... ... ... | 5·08 |
| Water ... ... ... .. ... ... | 33·75 |

The market-standard of boric acid has, however, been determined to be at the rate of 44 per cent., which is the quality obtained from the Chilian mines, and this forms a guide for estimating the *pro rata* difference in price of mineral containing a lower percentage.

The quoted price of borate of lime containing 44 per cent. of boric acid in the London market in March, 1899, was at the rate of £13 10s. per ton; in the following April, it fell to £11 10s.; in September of the same year it was offered at £10; and in October at £9 10s. In 1900, one of the largest workers of borate of lime made offers at the rate of £6 per ton. However, more recently, a reaction set in, and offers were made at £9 per ton. It is therefore certain that, owing to the law of demand and supply, this mineral, like various other commercial articles, suffers violent fluctuations in the market-price.

Under such circumstances, it would prove exceedingly difficult to settle or fix a definite price beforehand, such, in fact, as would remain for any length of time. Nevertheless, such a determination must be made with a close degree of certainty, when the question arises as to the commercial value of any particular mine or mineral district containing borate of lime.

For the object of this paper, and to make a fairly accurate comparison, it is assumed that the average selling-price of borate of lime containing 44 per cent. of boric acid would be £9 per ton. The mineral extracted from the mines of the National Territory of the Andes would not, however, exceed 39·53 per cent. of boric acid, and would suffer a *pro rata* reduction in selling price compared to the standard percentage.

| | Per Ton. £ s. d. |
|---|---|
| For example:—44 per cent. : 39·53 per cent. = £9 : the selling-price delivered in England ... ... ... | 8 1 9 |
| Total estimated cost of production ... ... ... ... | 8 7 11 |
| Loss ... ... ... ... ... | £0 6 2 |

*Province of Jujuy.*—The borate-of-lime deposits existing in the province of Jujuy are considerable, and feeble attempts have been made from time to time to work them; but good results were not obtained.

Recently a Belgian company has undertaken to work a group of these mines, and it would appear that this company thought that the national government intended to construct a railway, which would pass near the borate-mines and so reduce the cost of transport, but this important work has not yet been commenced.

The principal borate-of-lime district in this province is situated at Tres Moros, and at a distance of 68 miles from the town of Jujuy. From the mines at Tres Moros to the nearest railway-station, situated at Cerrillos in the province of Salta—by the Quebrado del Toro—the distance is 112 miles.

The transport of the mineral by the first-named route is at the rate of 35 paper dollars, and by the second route, it amounts to 45 paper dollars, and is partly effected by pack-mules and common horse-carts; and although the route by the way of the Quebrado del Toro is longer than the first-named still, on account of the greater facility which it offers, the major portion of the mineral passes by that route.

Taking the other expenses of working, etc., to be equal to those already given for the mines in the National Territory of the Andes, the total cost per ton by the first-named route would amount to 62·10 paper dollars, and for the second route, or by the Quebrado del Toro, it would amount to 72·10 paper dollars. In both cases the mineral is delivered at the port of Colastine. There exists, therefore, a difference in the one case of 23·50 and in the other of 13·50 paper dollars per ton in favour of the working of the mines in the province of Jujuy, as compared with those in the National Territory of the Andes.

The Belgian company carry wood from the nearest forests in the province of Jujuy to their mines at Tres Moros, for the object of what is called calcining the mineral, that is, drying it. To perform this operation, special heating-stoves with a large superficial area have been constructed, and upon the floor of these stoves the mineral is thinly spread and frequently turned until all the humidity has been evolved. The mineral is then placed in bags for transport.

The cost of the transport of the wood and of the labour in drying the mineral has not been ascertained, but considering that but little heat is required to dry the mineral it cannot be large.

| | Per Ton. Dollars. | Per Ton. £ s. d.* |
|---|---|---|
| Estimating, therefore, the cost of wood and labour in drying to be no more than ... | 3·00 to 3·00 | 0 5 2 to 0 5 2 |
| Expenses of working, transport, etc. ... | 62·10 ,, 72·10 | 5 6 2 ,, 6 3 4 |
| Total cost on ship-board at the port of Colastine | 65·10 ,, 75·10 | 5 11 4 ,, 6 8 6 |
| However, the 33 per cent. of reduction in weight affects the total estimated cost of transport per ton of mineral in the same proportion, that is ... ... ... | 16·20 ,, 19·50 | 1 7 8 ,, 1 13 4 |
| Reduced cost per ton, due to the calcination | 48·90 ,, 55·60 | £4 3 8 ,, £4 15 2 |

* These values have been reduced to an English standard, at the rate of exchange of 2·32 paper dollars as equivalent to 1 gold dollar, and allowing the usual 5·04 dollars to the English sovereign.

The difference shows in favour of the operation of drying the mineral, and this would follow even if the cost were to be considerably augmented.

| | Per Ton. £ s. d. | £ s. d. |
|---|---|---|
| The amount or cost delivered on board in the port of Colastine, would be ... ... ... ... ... | 4 3 8 | and 4 15 2 |
| Cost of transport of 13·4 cwts. of dry mineral to Liverpool | 0 13 5 | ,, 0 13 5 |
| | 4 17 1 | ,, 5 8 7 |
| Warehousing, commissions, insurance, etc. ... ... | 0 1 6 | ,, 0 1 6 |
| Total cost delivered in England ... ... ... | £4 18 7 | ,, £5 10 1 |

Other deposits of borate of lime exist at Guanacayo and Corales, situated about 20 leagues to the north of the town of Jujuy; but only a few concessions have been granted, and no exploitation has been entered upon.

*Province of Salta.*—In the department of San Antonio de los Cobres, in this province, borate-of-lime deposits occur near to Niño Muerto; further to the north in the same department various other deposits also exist. Eight concessions of borate-of-lime-mines only have been obtained in these localities.

In the department of Poma, also in the same province, other deposits of borate of lime are found. The distance from the mines situated in the department of San Antonio de los Cobres to the railway-station at Cerrillos is about 30 leagues, or three days' journey for pack-mules, and the distance from the mines at Poma is about the same.

The national government has constructed a high road from the railway-station at Cerrillos, passing by San Antonio de los Cobres, and at about 8 leagues from the mines in the direction of the high lands of the National Territory of the Andes; but it has not yet reached those regions.

### 3. Chile.

In this Republic, three important districts of borate of lime are known, namely:—(1) Ascotan, (2) Salinas Grandes, and (3) San Pedro de Atacama. The first is situated near to the old volcano of the same name. The railway-station of Ascotan is situated in south latitude 22 degrees 27 minutes 30 seconds and west longitude 68 degrees 25 minutes 0 seconds.

According to the best information to be obtained, the concessions of the borate-of-lime mines of Ascotan are now exploited by the London Consolidated Borax Company, which seems to have made a branch railway from the mines to Ascotan on the Great Trunk railway running to Antofagasta. The cost of transporting the mineral is at the rate of 16 paper dollars or £1 7s. 4d. per ton, and adding the cost of transport from Antofagasta to England, or £2 per ton, the total cost delivered in England will be £3 7s. 4d. per ton. If we take the cost of working at the same rate as that estimated for the mines of the National Territory of the Andes and those of Jujuy:—

| | Per Ton. £ s. d. |
|---|---|
| The estimated cost would be ... ... ... ... | 5 18 10 |
| Warehousing, commissions, insurance, etc., say ... | 0 1 6 |
| Total estimated cost ... ... ... ... | £6 0 4 |

The borate-of-lime-deposits in the republics of Peru, Bolivia, and Argentine, contain water at the rate of 35·8, 32·35 and 33 per cent. respectively, consequently it is presumed that the same class of mineral in Chile would not contain less than 33 per cent. of water.

Exclusive of transport by sea, the calculations have been taken upon the production of crude humid-mineral delivered near to the port of Antofagasta for calcination or drying. Instead, therefore, of transporting by sea 1 ton of crude wet mineral at the rate of £2 per ton, the drying process reduces it to 13·4 cwts.:—

| | Per Ton. £ s. d. |
|---|---|
| Costing ... ... ... .. ... ... ... | 1 6 10 |
| Exploitation, drying, etc. ... ... .. ... | 2 11 5 |
| Carriage of mineral from mines to Antofagasta ... | 1 7 4 |
| Contingencies, insurance, and commissions, say ... | 0 1 6 |
| Total cost delivered in England ... ... | £5 7 1 |
| Offers to sell dried borate of lime at ... ... ... | 6 0 0 |
| Estimated profit per ton .. ... ... ... | £0 12 11 |

If, however, the mineral had been sold in its crude damp condition, there would have been a loss of 4d. per ton, and the difference between the cost of the mineral in its two conditions, that is, dry and humid, has been already exhibited.

The drying-kilns of this company are situated near to Antofagasta, and the mineral, as before intimated, is brought from the mines at Ascotan by a branch-railway to the trunk-railway communicating with Antofagasta.

The borate-of-lime-mines situated in the locality of the Salar of Atacama, and those of Salinas Grandes are at a considerable distance from the coast, and considering that the mode of transport is not equal to that by railway to Antofagasta, the mines are worked upon a much smaller scale than those of Ascotan.

### 4. Peru.

A deposit of borate of lime of considerable extent exists near Arequipa, behind the Misto volcano, and when easy transportation can be obtained the mines will prove very important.

An incomplete analysis of the borate of lime of this district is as follows:—

| | Per cent. |
|---|---|
| Boric acid | 45·90 |
| Soda | 7·80 |
| Lime | 4·80 |
| Water | 35·80 |

### 5. Bolivia.

An analysis of the borax mineral of Bolivia is as follows:—

| | Per cent. |
|---|---|
| Boric acid | 38·74 |
| Soda | 13·23 |
| Lime | 13·83 |
| Potash | 0·68 |
| Magnesia | 0·21 |
| Water | 32·35 |
| Sand and earth | 0·96 |

### 6. United States.

*California.*—Boric acid is obtained from some of the lakes and from clay or mud-deposits; but the greater part is reduced from the boro-calcite mineral extracted from the mines in the Calico district of San Bernardino county, California. A vein of this mineral has been traced for a distance of 2 miles in the mountain-regions; but this deposit is not regular, varying from a few

inches up to 12 feet in thickness. The mineral is worked by pits and galleries.

One of the mines has attained a depth of 400 feet, and the mineral extracted contains from 15 to 50 per cent. of anhydrous boric acid. The yield of calcium borate from the mines in the district named has yearly augmented; and, in 1899, it amounted to about 21,000 tons. Taking the average assay at 32·5 per cent., the yield of boric acid would amount to 6,825 tons.

Consequent upon the inclination of the corporations engaged in this industry to observe secrecy with reference to the cost of production and profit, it is difficult to give absolute figures. Still it has been deduced from private enquiry that the extraction of the mineral and placing it on the surface costs about 5s. (1·25 gold dollars) per ton. The mineral is dried upon kilns, two of which dry 100 tons of mineral daily, so that the cost per ton cannot be excessive. These mines supply mineral to three refineries, one of which is in California, a second near New York City, and the third in Chicago. There are four companies engaged in this class of mining and in refining the mineral, the largest being the Pacific Coast Borax Company and the other three are Californian concerns.

The output of boric acid in the United States in 1896 amounted to 233 tons.

The Pacific Coast Borax Company has a railway, 12 miles long, from a point at Daggett, on the South Pacific railway, to the borocalcite mines, and about half the mineral extracted from the district named is sent to England, the rest, as previously noted, being distributed between the refineries.

As near as could be ascertained, the cost of materials and labour for refining the crude minerals, including the mining and contingencies, is about one-half of what the refined product is sold for, so that the profit may be estimated at the rate of 50 per cent. upon the capital employed.

It is curious to note that in the United States the demand for boric products exceeds the supply, and consequently a considerable quantity was imported and a duty paid upon it amounting to ¾d. (1·5 cents) per pound.

### 7. Annual Production.

The following table exhibits the borate-output of some of the principal countries concerned in 1898:—*

* *The Mineral Industry*, 1900, vol. ix., page 58.

| | Tons. |
|---|---|
| United States—Calcium borate ... ... | 21,800 |
| Chile do. ... ... | 11,951 |
| Peru do. ... ... | 7,638 |
| Italy—Crude boric acid ... ... ... ... | 2,674 |
| Germany—Boracite ... ... ... ... | 183 |

For 1898, no return is to hand of the produce of Turkey, but supposing it to be the same in 1898 as it was in 1897, namely, 11,375 tons, the total yield of borate-mineral-producing countries would amount to 52,947 tons. If the average yield of boric acid were to be at the rate of 35 per cent., then the total yield would amount to 18,531 tons, and if the output of Italy be added, the gross production of boric acid attains 21,205 tons.

### 8. Technical Modes of Treating Boric Mineral.

*Moore Process.*—Various methods have been proposed for the economic treatment of borate-mineral, such as those of Gootch, Rosenblatt, and others; but the Moore process* seems to fulfil the required conditions. The crude borates, such as those of calcium or magnesium, are finely powdered and mixed with water, or the mother liquid of a previous operation. Chlorine is passed into the liquid, which is maintained at a temperature of 60° or 80° Cent. The boric acid may be crystallized out or separated by cooling to, say, 10° Cent. The reduced liquid may be used for a fresh batch of crude borate, or the chlorates and chlorides may be separated by known methods. The boric acid may be purified by crystallizing, or it may be converted into borax by treatment with caustic or carbonate of soda. This process is particularly useful when the chlorine and soda are produced electrolytically, as both the products can be utilized.

*United States Process.*—Some companies treat the lower-grade borates which exist in extensive mud-deposits in the following simple fashion. After the mud has been ground to a slime and brought to a boiling condition, sulphuric acid is added, and the boric acid is liberated in the solution. It is filtered through specially constructed filters, and then cooled and crystallized in the usual manner. The Western Mineral Company modifies this process by treating the cold, unground mud with sulphuric acid direct, and thus liberating the boric acid, which is washed out from

* British patent, No. 20,384, 1899.

the treated mud. The liquid is then evaporated by solar heat and afterwards cooled and crystallized. From this condition it is manufactured into commercial borax and boric acid, at the works situated at Bayonne, New Jersey.

The boric acid is extracted from the boro-calcite mineral derived from the other mines in the United States in the usual way; it has not, however, been ascertained how much sulphuric acid is required to reduce a ton of boro-calcite, but the quantity of acid necessary to reduce a given weight of borate-mineral depends upon the quantity of calcite contained in it, and may be determined by experiment in the laboratory. Also the quantity of carbonate of soda to be employed with the boric acid to constitute borax depends upon the amount of lime present.*

*Theoretical Ideas upon the Extraction of Boric Acid in the National Territory of the Andes.*—Opinions have been expressed in reference to the advantages to be gained by erecting an establishment in the National Territory of the Andes, for the extraction of boric acid from the borate-minerals; but evidence has been advanced that such opinions were only speculative, and were not practical, for the reason that they were not based upon personal knowledge of the great difficulties to be encountered nor the ways and means to be employed.

No pyritic mineral from which sulphuric acid could be manufactured has as yet been discovered in these altitudes, and if such mineral exists it must be sought for in the mountain-districts near the Andes and at a long distance from the borate-mines. If rich deposits of pyritic mineral existed in abundance, an establishment would have to be installed near to the pyrites-mines in order to manufacture the acid, and for this object all the materials required would have to be transported by pack-mules, probably eight or ten days' journey, to an altitude of nearly 19,000 feet above sea-level.

Under such circumstances, and for the reduction of the borate-mineral to boric acid at the mines, sulphuric acid would have to be transported, as also the wood required for heating purposes, and all other materials, as also the necessaries for the maintenance of life.

* *The Mineral Industry*, vol. i., page 43; vol. ii., page 75; vol. iii., page 84; vol. iv., page 51; vol. v., page 57; vol. vi., page 61; vol. vii., page 90; vol. viii., page 64; and vol. ix., page 57.

Considering, therefore, that in those elevated regions no resources of any kind exist, not even good water, the cost of living and labour would be as uncertain as it would be expensive, and taken in connection with the inconstancy of workmen in such places, it must appear that an operation such as that suggested would be exceedingly difficult and costly and almost impossible.

### 9. Practice of Extracting Boric Acid in the Argentine Republic.

A small establishment for refining borate of lime and for the manufacture of borax, has been established at Palermo, in the vicinity of Buenos Ayres, for a considerable time, and is still in operation. At the commencement, the cost of this establishment amounted to the small sum of £427 (5,000 dollars), and was only capable of treating 25 tons of crude mineral per month, resulting in the production of 10 tons of boric acid in crystals, or a yield of 40 per cent. The crude borate of lime treated at this establishment was purchased in the province of Salta, and when transported to the establishment the cost was at the rate of 90 paper dollars or £7 13s. 11d. The cost of 25,000 kilogrammes or 25 metric tons of borate of lime, including transport with materials, labour and incidental expenses required in the process of refining, amounted to a total of 4,200 paper dollars or £359 3s. 11d., or at the rate of 168 paper dollars or £14 7s. 4d. per ton.

However, the yield being only at the rate of 40 per cent., there are 400 kilogrammes or 881·848 English pounds of boric acid produced from 1 ton of crude mineral; and 400 kilogrammes at 28 gold cents equals 112 gold dollars or £22 4s. 5d.

The refined boric acid in crystals was sold in Buenos Ayres at the rate of 28 cents gold per kilogramme of 2·2046 English pounds, or a total of £55 11s. 1d. per metric ton.

| | Paper Dollars. | Gold Dollars. | £ | s. | d. |
|---|---|---|---|---|---|
| Selling price ... ... ... ... | 259·84 | 112·00 | 22 | 4 | 5 |
| Cost of production ... ... ... | 168·00 | 72·41 | 14 | 7 | 4 |
| Profit per ton of crude mineral, or 400 kilogrammes or 881·848 pounds of boric acid ... ... | $91·84 | $39·59 | £7 | 17 | 1 |

The quantity of sulphuric acid employed in this establishment in the process of refining the borate of lime was at the rate of 1 part of the former to 3 of the latter, that is, for every 100 kilo-

grammes of mineral 33 kilogrammes or 72·75 pounds of sulphuric acid was employed, or a total of 330 kilogrammes or 727·53 pounds of acid for a metric ton of 1,000 kilogrammes or 2,204·6 pounds.

The mode of preparing borax from borate of lime in the Argentine republic is that of employing common commercial carbonate of soda in the proportion of about 45 per cent., instead of using sulphuric acid. In this case, the borate of lime is intimately mixed with the carbonate of soda, and saturated with boiling water, and when the mixture has been boiled sufficiently to extract the boric acid, the solution is filtered, and the filtrate passes into a receptacle, and may be evaporated or otherwise, and submitted to a low temperature, when crystallization takes place, the produce forming common commercial borax. When experimenting in the laboratory, it is more convenient to employ hydrochloric acid instead of sulphuric acid: the solution thus formed would be clearer, and would pass the filter in less time.

When it is required to procure boric acid in thin shining crystals or scales, a proportionate quantity of albuminous substance is employed such as the crude white of eggs, and is mixed in the solution before it is submitted to the process of crystallization. The combination of the boric acid and carbonate of soda yields a total of about 85 per cent. in crystals.

Common carbonate of soda is sold in the Argentine republic at 11·28 paper dollars or 4·86 gold dollars or £0 19s. 3d. per 150 kilogrammes, or at the rate of 0·032 gold dollars or 1½d. per kilogramme.

The manufactured borax or borate of soda is sold in Buenos Ayres at from 0·16 to 0·18 gold cents per kilogramme. Taking, therefore, the average at 0·17 cents, a metric ton, or 2,204·6 English pounds, would be worth 170 gold dollars or £33 14s. 7d. And a British ton would be worth 172·73 gold dollars or £34 5s. 5d.

### 10. Borax-mineral.

As previously noted, boric acid occurs in different forms and is found mixed with various other substances such as bi-borate of soda, in various parts of South America, Ceylon, China, Persia and Thibet. Some of the borax lakes in California have yielded considerable quantities of this substance. The water of some of

these lakes contains borax in solution, so that it is not surprising to find it deposited near the margin of the lakes. It is stated that the water of "Borax Lake," California, contained 25 per cent. of carbonate of soda, 50 per cent. of chloride of sodium and 25 per cent. of boric acid; and, considering the nature of this chemical combination, it is not difficult to imagine how the large bed of borax-crystals was formed at the bottom of the lake.

The curious mode of obtaining crystallized boric acid in Tuscany, Italy, is well known.

The following list exhibits various mineral substances containing boric acid with the percentage yield of each:—

| | |
|---|---|
| Axinite, boro-silicate of alumina, iron, etc. ... ... ... | 2 to 5 |
| Boracite, borate of magnesia ... ... ... ... ... | 61 ,, 62 |
| Botryolite, boro-silicate of lime .. ... ... ... ... | 18 ,, 20 |
| Cryptomorphite, hydrous borate of calcium and sodium ... | 5 |
| Datholite, boro-silicate of lime ... ... ... ... .. | 18 to 20 |
| Hydroboracite, borate of lime and magnesia ... ... ... | 41 ,, 48 |
| Lagonite, hydrous borate of iron... ... ... ... ... | 48 |
| Larderellite, hydrous borate of ammonia ... ... .. | 68 |
| Ludwigite, borate of iron and magnesia ... ... ... | 16 |
| Priceite, borate of lime ... ... ... ... ... ... | 49 to 50 |
| Rhodizite, lime boracite ... ... ... ... ... ... | 30 ,, 45 |
| Stassfurtite, boracite ... ... ... ... ... ... | 61 |
| Sussexite, hydrous borate of manganese and magnesium ... | 32 |
| Szaibelyite, hydrous borate of magnesia... ... ... ... | 37 |
| Tinkal, borate of soda ... ... ... ... ... ... | 36 to 37 |
| Tinkalzite, borate of lime ... ... ... ... ... ... | 37 |
| Tiza, boro-natro-calcite ... ... ... ... ... ... | 30 to 40 |
| Tourmaline, boro-silicate of aluminium and magnesia ... | 2 ,, 8 |
| Ulexite, boro-natro-calcite, or hydrous borate of calcium and sodium (hayesine) ... ... ... ... ... ... | 42 |
| Warwickite, boro-titanate of iron and magnesium ... ... | 27 |

## 11. Theoretical Considerations upon the Formation of Boric Acid.

Two forms of boron have been recognized, one as a greenish-brown amorphous powder, slightly soluble in water, and the other (adamantine) crystalline, and with a lustre and hardness inferior only to that of the diamond. Boron does not, however, occur in nature in a free condition; but it may be prepared by treating boric acid at a high temperature, with some powerful reducing agent.*

* Watts' *Chemical Dictionary*.

Sulphide of boron is said to be a white crystalline body, decomposed by water.

Amorphous boron is a greenish-brown powder: it burns in oxygen, and gives off boric acid; and, at a red heat, it decomposes water and forms the same acid and hydrogen.

Carbon boride, crystallized from fused copper, is a black crystalline substance, igniting when heated in oxygen at 1,832° Fahr.; but it burns with difficulty, because the boric anhydride produced forms a protective film. It is insoluble in all acids, but is attacked by fused alkalies.

Basalt fuses at 2,250° Fahr., while rhyolite is still viscid at 3,100° Fahr. The lower temperatures of volcanic effusions are characterized by steam, carbonic acid, etc., while with the higher ones are associated fluoric and boric acids.*

The elements of water may even be retained in fused compounds at the temperature of ignition under ordinary atmospheric pressure, as seen in hydrates, and acid sulphate of potassium: but in certain vitreous borates of sodium and potassium, which at a red heat and in tranquil fusion hold an amount of hydrogen equal to 1·2 and 1·3 hundredths of water, and are, under these conditions, slowly decomposed by metallic iron with abundant disengagement of hydrogen gas, which burns with a green flame from the presence of combined boron.†

Various theories have been advanced, with the view of explaining the origin and formation of boric acid; but the difficulties surrounding the question have impeded an accord in opinion and definite solution.

However, the most probable theory of the formation of boric acid is that at undefined depths in the crust of the earth, rocks containing the elements of boric acid exist, and that these being acted upon by alkaline substances in a fused condition, together with the action of other elements, boric acid has been liberated, and being mixed with hot, humid, sulphurous and other gases, have ascended together through volcanic craters, cracks and fissures in the strata, and finally coming in contact with cold air have become condensed, thrown down; and meeting with other mineral elements, probably in solution, such as carbonate of lime, would, on concentration and consolidation, form

* *Manual of Lithology*, by — Williams, 1895, page 326.

† *Mineral Physiology*, Prof. T. Sterry Hunt, page 221.

the mineral known as priceite, and others, as also with various other elements such as sodium carbonate, sodium chloride, sodium sulphide, and other alkaline and acid elements, as is seen by an inspection of the preceding classified table.

When in solution, such mixed elements, as those indicated, would flow or be carried to lower levels and deposited in open fissures of the rocks and also in lakes, and, in some cases veins of borate of lime, etc., would be formed, and in the course of time become solidified and partly crystallized between the rocks.

A similar process to that described must have taken place in other surface-depressions, some of which afterwards became lakes. When the water was evaporated, or the ground raised, a compact mass of borate of lime and other similar substances would remain, and afterwards become covered with surface-soil. The borocalcite veins in California, and the surface-deposits in South America and other places, were undoubtedly formed in some such similar manner.

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The PRESIDENT moved a vote of thanks to Mr. C. A. Lynes Hoskold for his interesting paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

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Prof. A. RATEAU's "Remarks on Mr. M. Walton Brown's Report on Mechanical Ventilators" was read as follows:—

# REMARKS ON MR. M. WALTON BROWN'S REPORT ON "MECHANICAL VENTILATORS."*

By Prof. A. RATEAU, Mining Engineer, Paris.†

The experiments carried out by the Committee of the North of England Institute of Mining and Mechanical Engineers and the Midland Institute of Mining, Civil and Mechanical Engineers are of great value, owing to the care with which they have been conducted. They are analogous to those formerly made in France by the Commission du Gard, but with this additional circumstance in their favour that, in the present case, it had been possible to compare appliances placed side by side on the same mine.

The explanations and the figures tabulated in Mr. Walton Brown's very complete *Report* are of extreme interest and value for the study of ventilators, and they offer ample opportunity for instructive remarks; and the writer has pleasure in setting forth the following observations which this *Report* has suggested to him.

First of all, he must express his entire approval of the system of making comparisons between appliances placed on the same mine. It is, in point of fact, difficult to compare accurately ventilators which are not working under identical conditions, owing to the appreciable errors of measurement which arise from the difference in the quantities that have to be measured, and more especially the volume of air. The writer has already drawn attention to this point in a note which was published in 1900.‡

The mechanical efficiency is expressed by the relation of two numbers, each of which is the product of two quantities that have to be estimated; in all, four elements are to be measured, the depression and the volume of air so far as the ventilator is

* *Trans. Inst. M.E.*, 1899, vol. xvii., page 482.

† Translated by L. L. Belinfante, M.Sc.

‡ *Revue Universelle des Mines, etc.*, Liège, vol. li., page 37.

concerned, the mean pressure of the steam and the speed of rotation so far as the engine is concerned. There is no difficulty whatever in estimating with accuracy the speed of rotation, but it is far otherwise with the three other elements.

As a rule, the measurement of the depression by means of a straight tube, which dips into a current flowing more or less swiftly, yields an exaggerated result. In order to ascertain what depression corresponds to the actual useful work accomplished by the ventilator, the measurement should be carried out by means of a Pitot tube with its face to the air-current at a spot (not too distant from the ventilator) where this current is practically uniform. Even so the depression thus measured varies from point to point, and if one wishes to be very accurate one ought to move the Pitot tube along the entire transverse section of the current and then take the mean of the results thus obtained. The writer gave precise details regarding this matter in his memoir of 1892 on turbo-engines.*

The measurement of the volumes is also attended with the risk of considerable error, when it is carried out by means of anemometers that alone are applicable to very large ventilators.

Mr. D. Murgue and the Commission du Gard pointed out in 1878† that anemometric estimates entail exaggerations of as much as 12 to 15 per cent. By means of more recent experiments‡ the writer has shown that this exaggeration is in part due to the inertia of the wheel and in part to the irregularity of the measured current. The greater this irregularity, the greater is the error in the anemometer-reading: therefore, the error may vary from one case to the next. Often below 10 per cent., it doubtless at times approaches 20 per cent.

Finally, all those who have handled a Watt indicator know that it is lacking in precision. There are many difficulties in the way of taring the instrument accurately, that is in determining the flexure of the spring at increasing pressures. A still

* "Considérations sur les Turbo-machines et particulièrement sur les Ventilateurs (Observations on Turbo-engines, and especially on Ventilators)," *Bulletin de la Société de l'Industrie Minérale*, St. Etienne, 1892, series 3, vol. vi., pages 47 to 228.

† *Bulletin de la Société de l'Industrie Minérale*, 1878, series 2, vol. v., page 505.

‡ "Expériences et Théories sur le Tube Pitot et sur le Moulinet de Woltmann (Experiments and Investigations upon the Theory of the Pitot Tube and the Woltmann Mill)," *Annales des Mines*, Paris, 1898, series 9, vol. xiii., page 331; and *Transactions of the Institution of Mining Engineers*, 1899, vol. xvii., page 124.

more fruitful cause of error is the manner in which the indicator-cylinder is connected to the two ends of the steam-cylinder. If the communicating tubes are long or narrow, the pressure registered at the indicator lags behind the true pressure existent in the steam-cylinder. The diagram thus obtained is more curved and of smaller area than the true diagram. By constricting, therefore, the connecting pipes, we may obtain an apparent power of the motor-engine far inferior to the actual power.

We see, then, that nearly all the causes of error met with in measuring the mechanical efficiency of a ventilator result in an exaggerated estimate of the efficiency, and, what is of serious import, the exaggeration may vary from one case to the next. This is the factor which stultifies the mutual comparison of appliances unless they are tried under identical conditions.

Thus it happens frequently enough that experiments made with the writer's design of ventilator yield a total mechanical efficiency, for motor and ventilator, of more than 80 per cent., which would imply, for the ventilator alone, more than 90 per cent. Now, the writer can estimate from other data that the real efficiency can hardly exceed 75 per cent. This gives some idea of the enormously exaggerated results shown by ordinary experimental methods, even when such methods are applied with the most scrupulous care.

On the other hand, we must not lose sight of the fact that a given ventilator only yields its maximum efficiency on a given equivalent orifice, proportional to the square of the radius of the ventilator, as the writer demonstrated in his paper of 1892. A perfectly just comparison can, therefore, be made only if the appliances work on their equivalent orifices at normal speed, or at least on an orifice which differs but little from that.

In addition to the experiments of the English Committee, set forth in Mr. Walton Brown's *Report*, we have on record some other experiments on ventilators placed side by side on the same pit. Among these may be specially mentioned the trials conducted by Messrs. A. Soupart and L. Legrand on a Guibal fan of 29·53 feet (9 metres), and on one of the writer's, of 9·18 feet (2·80 metres)*; also those of the Monopol colliery on the Mortier fan of 9·18 feet (2·80 metres), and on one of the writer's of 13·12 feet

* *Revue Universelle des Mines*, Liège, 1900, series 3, vol. 1., page 44.

(4 metres).* The writer may be allowed to observe by the way that these experiments, as well as many others, have shown that the combined mechanical efficiency of motor and ventilator, carefully measured according to the ordinary methods, exceeds 65 per cent. and sometimes attains 82 per cent. in ventilators erected according to his designs, while the ventilators with which the English Committee experimented only showed (according to the curves tabulated at the end of their report) an efficiency of less than 60 per cent.

We may also recall the very exhaustive comparative experiments made some years ago by Mr. Bryan Donkin with small ventilators, the results of which were published in 1895.† Mr. Donkin took every precaution necessary to ensure accurate results, and his experimental methods conformed in every respect to the data contained in the writer's memoir of 1892. The pressure and volume of the air were estimated by means of a Pitot tube.

The writer will now make some remarks on the theoretical questions dealt with in the report of the English Committee. It is stated‡ that the theoretical depression yielded by a centrifugal ventilator, may be calculated by means of the expression $u^2/g$, $u$ being the peripheral speed, and the depression being estimated in terms of an air-column. There is doubtless some misunderstanding on this point. If it is desired to calculate what we may term the manometric efficiency, one does indeed compare the depression really yielded by the ventilator with that figured out by means of the expression $u^2/g$, but this is only a term of comparison, not by any means the theoretical depression. This

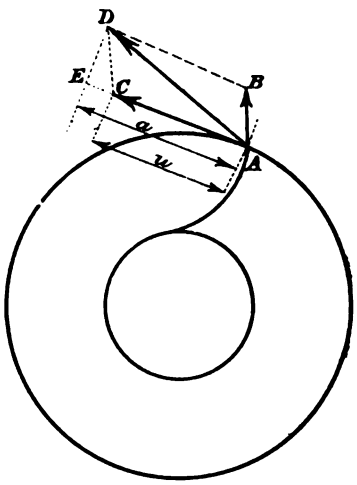


FIG. 1.

* "Conditions d'Exploitation à Grande Profondeur (The Working of Mines at Great Depths)," by Léon Poussigue, *Bulletin de la Société de l'Industrie Minérale*, 1900, series 3, vol. xiv., page 193.

† *Proceedings of the Institution of Civil Engineers*, vol. cxxii., page 265.

‡ *Trans. Inst. M.E.*, vol. xvii., page 503.

is obtained, for a centrifugal ventilator, by the somewhat less simple formula $H=\frac{au}{g}$, where $a$ is the projection, $AE$, of the absolute velocity of issue, $AD$, on the tangential speed, $AC$ (Fig. 1). Consequently, in ventilators with forward blades the theoretical depression may be much greater than $u^2/g$.

Attention may be drawn to another point. It is stated* that the volume of air produced by a ventilator may be calculated by means of the formula $V=39u\sqrt{\frac{2Ka^2o^2}{a^2+o^2}}$, where $u$ is the peripheral speed, $a$ the orifice of the ventilator, and $o$ the equivalent orifice of the mine. This ratio is approximately accurate in the case of

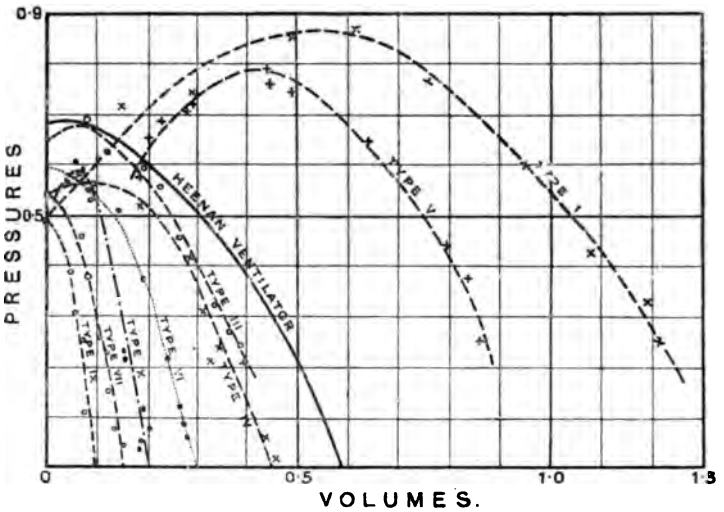


Fig. 2.

Guibal fans, and perhaps also for the other types that are used in English mines, but it does not apply to some of the modern fans used in France, Belgium and Germany. This may be shown very clearly. If in the foregoing formula, for instance, we substitute for the equivalent orifice, $o$, its value in terms of the volume, $V$, and the depression, $H$, we shall obtain a ratio between the volume, $V$, and the depression, $H$, which, for a given ventilator, will be expressed by the equation: $H=b_1u^2-b_2V^2$, in which $b_1$ and $b_2$ are constants. More generally still, whatever may be the speed of rotation of the fan and its dimensions, if we make use of the mano-

* *Trans. Inst. M.E.*, vol. xvii., page 513.

metric efficiency, $\mu = \frac{gH}{u^2}$, and of the volume-coefficient which the writer defined in 1892, $\delta = \frac{V}{ur^2}$, then $\mu = c_1 - c_2\delta^2$ in which $c_1$ and $c_2$ are constants.

The characteristic curve of the manometric coefficient, $\mu$, in terms of the volume-coefficient, $\delta$, would consequently be a parabola, with its summit on the axis of $\mu$ and its concavity turned downward. This is approximately accurate, so far as the Guibal and many other fans are concerned. But it is by no means accurate for some types of fan, especially those wherein the blades are inflected forward in their penultimate portion. Thus, in Fig. 2, which illustrates Mr. Donkin's experiments, giving the curves of $\mu$ in terms of $\delta$ for the various types that he examined, we may see that these curves are indeed parabolic, but that occasionally their summit is very far from being on the axis of $\mu$. This divergence is very marked in the case of the curve of No. 1 type (which happens to be a fan of the writer's design). The writer made the same observation in discussing Messrs. Heenan and Gilbert's paper on "Centrifugal Ventilators" at the Institution of Civil Engineers on December 17th, 1895, and it agrees with the view expressed by Mr. H. Innes, regarding centrifugal pumps, in his work on those pumps and on hydraulic motors.*

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Mr. Emile Harze (Directeur-général Honoraire des Mines de Belgique, Brussels) wrote that he was as ignorant of the technical language of eminent British engineers as he was indeed of the tongue of Shakespeare. And therefore, in order to form the very simplest notion of the contents of the *Report*, he had perforce recourse to the kindness of his former colleague and friend, Mr. Armand Halleux.

The experiments had been carried out with a sedulous care, upon which the Committee deserve the most sincere congratulations, and they provide further data on the important problem of the ventilation of mines. But precisely because they are so successful in this respect, they, as Belgians, from their standpoint, might be permitted to express regret that the experiments are concerned only with such old-fashioned ventilators as the Waddle, the Schiele and the Guibal. The fact that such appliances alone

* *Centrifugal Pumps, Turbines and Water-motors*, second edition, page 171.

are used in Great Britain (the writer was concerned here only with depression-producing ventilators) was explicable when one recollected that the mines of Britain offer comparatively little resistance to the circulation of vast volumes of air, while in Belgian mines engineers are led to aim at ever increasing depressions.

He (Mr. Harzé) had also a subsidiary remark to make, in regard to what he might call "the general philosophy of mechanical work" in the above-mentioned *Report*. Therein a great deal is said concerning the equivalent orifice both of the mine and of the ventilator. From the aforesaid special (that is, the philosophical) standpoint it may be observed that, in working on the mine, the ventilator must induce a certain depression, in order to exhaust a certain volume of air, despite a whole series of retarding frictions in the mine. While, to induce the passage of air through an orifice in a thin-plate, the necessary energy is derived not from friction, but from the speed communicated to the flowing current. The effects which fall to be determined, one of which is a measure of the other, are then of entirely different nature. However, the work to be produced in both cases is the same, at least within the limits of practice, whatever be the speed of the ventilator or the variation in the volume that has to be exhausted. What precedes has then, at bottom, no bearing beyond ensuring the precision of scientific language.

The *Report* does not, in his (Mr. Harzé's) opinion, emphasize with sufficient explicitness the important part played by the resistance proper to the ventilator in the efficiency. And yet that is a point on which full light should be thrown. Thus, it is quite possible to conceive that, if working on a very resisting mine, a ventilator which itself offers considerable resistance to the passage of air, may yield an excellent useful effect, while the very same appliance working on a less resistant mine will yield a very scanty useful effect. This may be best understood by comparing the results yielded by steam-engines of the same efficiency, but of very different power. Let us consider, say, two engines with the same theoretical useful effect, one of 100, the other of 5 horsepower. The first, attached to a shaft which has to do a duty of 2 horsepower, will have a very poor efficiency, while the other under precisely the same conditions will have a reasonable efficiency.

It is true that the equivalent orifices of the several ventilators which were experimented with are calculated,* but an analysis of

* *Trans. Inst. M.E.*, vol. xvii., page 517.

the beautiful diagram (Fig. 46 of Plate XXXI.) confirms the views which have just been expressed.

All this is said while fully recognizing the extreme value of the Committee's work, and under the reservations which he (Mr. Harzé) must necessarily make in the absence of a literal translation of the *Report*.

Mr. HUGH WADDLE (Llanelly) wrote that Prof. Rateau had rightly emphasized some of the difficulties in connection with obtaining accurate results when testing fans and engines, and the enormously exaggerated results often shown by the ordinary experimental methods; and such causes sufficiently explained the remarkable results claimed by some fan-designers and makers. In the experiments under discussion, errors due to inaccuracy of measurement appeared to have been avoided as far as possible, and where such errors did occur, it was probable that the loss or gain to each fan of a pair under comparison would be approximately equal. So far as concerned a comparison of the actual fans and engines which were experimented on, the objects of the Committee appear to have been attained. It was an unfortunate feature that an impression appeared to have been given to engineers on the Continent, that the fans tested were the modern representatives of their respective types. How far this might be the case with the other types of fans tested he was not prepared to say, but the Waddle fans were of obsolete makes. There were now Waddle fans at work which had been running for over 40 years, but since they were made a gradual evolution had been taking place in the design, and it would be manifestly absurd to judge a modern Waddle fan by the results obtained from some of the earliest types, such as those tested by the Committee.

The greatest of the improvements had been made since the date of the most recent of the Waddle fans that were tested, namely that at Cwmaman colliery, which was erected about 15 years ago. The Cwmaman fan was of better design than the other fans tested, but there was an immensely greater difference between the modern Waddle fan and the Cwmaman fan, than between the latter and the other old Waddle fans tested. It should further be remembered that even the Cwmaman fan was much handicapped, by the method of driving by means of geared wheels from a marine engine too large for the work. If the *Transactions* were only read

by British engineers, the above statements would hardly be necessary, the facts being already well known in this country; but that they were not equally well known abroad, was shown for instance, by Mr. Emile Harzé's remarks.

The PRESIDENT (Mr. J. S. Dixon) proposed a vote of thanks to Prof. Rateau for his interesting remarks upon the report of Mr. M. Walton Brown on "Mechanical Ventilators."

Mr. JAMES STIRLING seconded the resolution, which was cordially approved.

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## DISCUSSION OF MR. J. A. JONES' PAPER ON THE "DEVELOPMENT AND WORKING OF MINERALS IN THE PROVINCE OF LEON, SPAIN."*

Mr. W. S. WELTON (London) wrote that, as the engineer who carried out the works of the Rio Sil and Leon Mining Company, he had examined the various gold-deposits of Medulas, Burbia, Valdeorras and the Duerna, and finally he decided to open works at the last-named locality, on account of the greater facility for obtaining water. Ditches were made and hydraulic works established at this point in 1886. It was soon found that the tailings would not be permitted to flow into the rivers, as the whole of the waters in this part of Spain were used for irrigation-purposes and the red mud from the gravels was very injurious to vegetation. Operations, however, might have been continued upon the richer portion of the gravels, by drifting, but for the circumstance that the Romans had already done this in a most remarkable manner. By accident, an opening into their works was made, at a distance of about 3 miles from the point attacked by the hydraulic installation, and the ancient drifting-works were found to be in perfect condition for a length of about 3 miles, the whole width of the channel having been drifted and the dirt washed, underground, in channels cut in the bed-rock, by tailing through a deep adit. The boulders and pebbles resulting from the washings had been built up into immense pillars which now support the roof, consisting of hard clay and gravel of moderate richness.

The upper gravel at all these deposits appears to be of an average value of from 1s. to 2s. per ton. And, at bed-rock, in the

* *Trans. Inst. M.E.*, 1900, vol. xx., page 420.

numerous shafts sunk and in the drives therefrom, it gave from 3s. to 5s. per ton, and at one place, as much as £3 5s. per ton, but this included some bed-rock, which had been found to be rich in gold. In the shafts and drives made by the company, ancient works were generally met with, and, for this reason, operations were suspended.

In the lower gravel, the gold was generally found in large rounded grains and, in the upper, in small thin flakes. The large nugget, weighing 33 dwts. 13 grs., was evidently a stone from a quartz-vein, as it consisted of quite 5 parts of compact quartz to 1 part of gold. He (Mr. Welton) had seen quartz-veins in Spain of considerable richness in gold, but in no case had the gold been as fine as that obtained from the alluvial washings, nor have these veins been in near proximity to alluvial deposits.

Mr. Ernest J. Bayliss (Madrid) wrote that he had found gold in more than payable quantities in the gravel-flats of the river Sil, where gold-dredging could be profitably undertaken. At Torral and Valdeorras (the valley of gold), these flats have a surface of over 600 acres each and the gold must have been washed down from the higher alluvial deposits and such auriferous lodes as at Menival. The mean section of the beds, taken from the surface downward, is as follows:—

| | Feet. |
|---|---|
| Gravel, sand and fairly large boulders, containing an average of 14 grains of gold per cubic yard ... ... ... ... | 10 |
| Plastic red clay, barren ... ... ... ... ... ... | 5 |
| Gravel, which has not yet been thoroughly proved, lying on a bed-rock of slate ... ... ... ... ... ... ... | 14 |

The gold is about 900 fine, and the usual shape is dust and flat lentils. One of these flats, he was informed, would be worked on a large scale by a British company.

The large deposits of arsenical auriferous pyrites also merited attention: he had taken samples that contained over 1 ounce of gold and 30 per cent. of arsenious oxide, although the average was about 12 dwts. of gold and 20 per cent. of arsenious oxide.

Mr. J. A. Jones wrote that the observations of Mr. Welton agreed with his own experience as to the difference of fineness of the alluvial gold, and of that from the reefs. While the former was about 900 fine, that from the reefs averaged 794, the combining balance in both cases being silver.

The alluvial beds which hold gold, are of two ages:—Those of Las Medulas, Paradaseca, and others, are extensive tracts of Miocene age; while those of the Sil river and its tributaries are the original beds of these rivers. The extensive gravel-flats about Valdeorras and Torral mentioned by Mr. Bayliss belong to the second series, and provided that the inherent surface-difficulties can be overcome, the working of these deposits on a large scale will doubtless yield good results.

Since the paper was written, opportunity arose for further exploration along the course of the Sil river, mostly in the vicinity of the village of Paramo del Sil. This village, lying on the left bank of the river, has been built upon a tableland of cement, which appears to have been the bed of the river long ages ago. The river has cut its present channel along the foot of the abrupt mountain-range forming its right bank. The cement overlies vertical blue-slate strata, shewing waterworn surfaces where the cement has been removed. The river has cut its bed through this, to a depth of 25 feet. The cement-plateau has a length of about 4,500 feet, an average width of 2,100 feet, a thickness of about 100 feet, and an area of 217 acres. The Romans worked the lower end of this bed very extensively, bringing water for the purpose from the higher reaches of the river, over the plateau. Their water-course can still be traced along this, to the top of the precipitous excavations which they have left. At the foot of these, the position of their sluices can also be traced. Along the bluff, forming the margin of the bed above the river, and the drainage-gullies, colours of about 1 dwt. to the ton were found in every pan.

The valley that fringes the river opens out from nothing to 2,500 feet for a length of 7,500 feet. In this valley, some work was proceeding. One of the marginal meadows was being excavated, and the gravel, drawn from below the surface-soil, was passed over rockers (boxes of a rectangular form with a semicircular bottom, a top of perforated-iron sheets with slot-holes, and open at the end). A blanket in the interior caught the heavy concentrate of black ironsand and gold.

The foreman shewed him (Mr. Jones) a deposit of concentrates, containing about 25 tons; and stated that he had not made a clean-up since starting work some 4 months before. He allowed him (Mr. Jones) to make several pannings of these, which resulted

in obtaining an average of 1 dwt. 12 grains per pan of 12 pounds. Thus the pile contained an average of 12 ozs. 8 dwts. 21 grains per ton, or about 311 ounces of gold for the whole pile. This he had secured with the work of 3 men, 2 women and 1 boy during a period of 4 months. He could only excavate to a depth of about 5 feet at the most, as water prevented him from going lower. Thus in no case had he reached bed-rock, where of course the best results would be held. Still, the results that he did obtain were marvellous, in view of the heavy loss accruing from passing the gravel over a flat surface, with a chance of the gold finding its way through the slots in the iron sheet, which may be estimated to be only about 30 per cent. of the gold held in the gravel. The gold comes in rounded grains and flat, but heavy, lenticular shapes, the whole measuring from dust up to ⅛ inch across. Doubtless, the same results will be obtained throughout the whole of this valley.

## DISCUSSION OF MR. JAMES STIRLING'S PAPER ON "THE GEOLOGICAL AGES OF THE GOLD-DEPOSITS OF VICTORIA."*

Prof. ARNOLD LUPTON (Leeds) said that an estimate was given in the paper of the quantity, in tons, of gold in the ocean. Taken out in sovereigns this would give something like 6,000,000 for every inhabitant of this world. He asked whether the statement was correct that he had recently heard made by an Australian geologist, from which he understood that coal was found continuously in Victoria for a depth of 700 feet and of good quality.

Mr. JAMES STIRLING (Victoria) said that the theory advanced as to the quantity of gold contained in the sea-water of Silurian times was that of Prof. Liversedge.

With regard to the 700 feet of coal, the facts were that brown coal was exposed in certain places in Victoria over a considerable area, and the Government carried on, under his predecessor in office, a series of bore-holes to determine the thickness of the seams. In one place, the bore-hole passed through a series of beds of brown coal, the first about 25 feet from the surface, was practically 25 feet thick; then followed layers of clay and gravel; and at a little over 100 feet an enormous deposit was passed through of brown coal about 265 feet thick, which was

* *Trans. Inst. M.E.*, 1900, vol. xx., page 442.

succeeded after various layers by another deposit of similar thickness. They left off boring at a depth of nearly 1,000 feet, and omitting the gravels and clay there was an aggregate of over 700 feet of coal. Samples of the cores were taken at intervals as the bore-hole continued, and the fixed carbon increased from 38 per cent. near the surface to 48 per cent. at the lower levels. It was perfectly true that the Tertiary coals were the thickest in the world. The beds of lignite overlay the Jurassic beds, and there was a distinct geological hiatus between the black and the brown coal-beds. The oldest beds in Victoria corresponded with those of Upper Austria and Bohemia, and the brown coal corresponded with those of the Rhine valley and central and southern Germany.

The gold-bearing quartz in Victoria might be shewn to be pre-Jurassic and post-Silurian, that was to say there was plenty of evidence to show that the quartz-veins found there were associated in their origin with the volcanic activity prevalent during the Devonian period; while there was little, if any, evidence to shew that any of the more recent quartz-veins contained gold. There was no evidence of contemporaneous gold-bearing veins in the Tertiary deposits of Victoria.

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## DISCUSSION OF MR. W. DAVID'S PAPER ON "THE POSITION OF AND METHOD OF WORKING BATH STONE IN THE QUARRIES OF THE BATH STONE FIRMS."*

Prof. A. Lupton (Leeds) said that he had had some experience in regard to Bath stone, and had been familiar with the mines for upwards of 40 years. The stone was most remarkable for the ease with which it could be cut. It was cheaply worked, and this no doubt was one of the great reasons for its extensive use, especially for ornamental buildings. It would be interesting to know why some of the stone became black so much sooner and so much more strongly black than other stone. Some of the houses in Bath were quite black, not from smoke but from a growth upon the stone, while other streets were not so. Having known Bath about 40 years ago, and having seen it again within

* *Trans. Inst. M.E.*, 1900, vol. xx., page 495.

the last 10 days, he was interested to notice that the black stone did not appear blacker than it did 40 years ago, and that the light grey stone did not appear to have changed its colour at all. He asked which part of the seam was it that went black, and which retained its natural colour?

Mr. M. Walton Brown suggested that the stone became blackened by the penetration of rain-water into the bedding of stones placed in a vertical position, and that the stone retained its colour, when laid on its natural bedding into which the rain-water was not able to penetrate.

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## DISCUSSION OF MR. FRED C. KEIGHLEY'S PAPER ON "COKE-MAKING AT THE OLIVER COKE-WORKS."*

Mr. T. Y. Greener (Crook), wrote that Mr. Keighley, in his interesting paper, not only described a large and well-laid out coke-yard, but quoted figures shewing results, so far as he was aware, not obtained from ordinary beehive coke-ovens in any yard in the county of Durham. Mr. Keighley claimed that the Oliver coke-works were the second largest in the world—probably they were if measured by the output of coke, but not if measured by the number of ovens in any one yard. At Bankfoot, near Crook, 731 coke-ovens are usually in operation, except during periods of commercial depression, but 108 of these ovens are of the Simon-Carvé type, hence in this country he (Mr. Greener) thought that there was not a coke-yard containing 708 beehive coke-ovens similar to those at the Oliver coke-works.

The coking-plant of Messrs. Oliver Brothers was designed to produce a blast-furnace coke to be used in their own furnaces, and the analysis of the coal from which it was manufactured compared favourably with the finest Durham coals. In some instances, the latter contained more fixed carbon than those to which Mr. Keighley referred, but he (Mr. Greener) would expect from the American coal not only a high-percentage yield but a good metallurgical coke. The yard seemed to have been specially designed so as to ensure a large output and economy of space, and to some extent the durability of the structure had been sacrificed to attain those objects. The coke-ovens were 12½ feet in diameter by 8 feet in height, a departure from the usual

* *Trans. Inst. M.E.*, 1901, vol. xxii., page 493.

practice adopted in this county of building beehive coke-ovens, generally speaking, 11 feet in diameter by about 8 feet in height. Most of the ovens in the older coke-yards of Durham were of the latter dimensions or less, although many recently constructed were of the same size as those at the Oliver works. He (Mr. Greener) thought that there was a distinct advantage in the larger oven, as it was not only more productive but, by reason of the larger quantity of coal carbonized at one time and the greater heat developed in the process, it improved the mechanical condition of the coke particularly from poor coal, and for blast-furnace use it was much more important to obtain a hard dense coke than to ensure a low percentage of ash at the expense of weight-carrying capacity. There was, of course, a practical limit to the size of beehive coke-ovens, and many people held that ovens 11 feet in diameter made the best coke and were the most economical to work, but in his experience, in many respects, the 12 feet oven was better. He was not surprised to hear that Mr. Keighley had had trouble and difficulty in upholding his ovens and that the cost of maintenance was heavy—they were built nearer together than they ought to be, and practically no space had been left for movement—there should not be less than 6 inches between each oven to allow for expansion and contraction by reason of the alternate cooling and heating occurring each time that the coke was drawn. The material employed in the original construction was also not the most suitable for the purpose. It was a mistake to use cement or lime in the erection of ovens, as the latter acted as a flux and destroyed the bricks, and he had known an entire row of ovens brought down from this cause. Good ground fire-clay made the best and most serviceable mortar for coke-oven work, and bricks consisting of half fire-clay and half ganister as a rule gave excellent results: they frequently wore, without renewal, for periods varying from 5 to 10 years. Whole ganister bricks could not be used in positions in which they were alternately hot and cold, as the action of the water used for cooling the coke caused them to disintegrate; they were, however, specially suitable for places subject to a constant high temperature, such as main flues, and in these positions they were invaluable. He (Mr. Greener) was not aware that ordinary clay was ever used in this country for filling between the ovens and the various walls of brickwork.

He would consider it most unsuitable for the purpose, for the reason mentioned by Mr. Keighley; and the usual practice was to fill any intervening spaces with fire-clay or old bricks and stones, which would be found very satisfactory. He observed that the ovens were placed back to back, as closely as possible, and undoubtedly considerable advantage was derived from this method of construction. Presumably two adjoining ovens were not drawn at the same time: hence the heat from the oven in full operation was communicated through the thin partition-walls to that which was newly loaded, consequently the ovens mutually assisted each other to burn off rapidly.

It was a pity that the waste-gases from the coke-yard were not utilized for steam-raising at the colliery; evidently, however, the ovens burnt out at the top as they did in Durham (30 years ago) prior to the introduction of flues. More heat could be obtained from the immense quantity of coal carbonized each day at the Oliver works than would be required to fire all the boilers used in connection with the colliery-operations.

The method of loading by means of one locomotive-road placed on solid brickwork, between two rows of ovens, was excellent: the tub or larry being, he presumed, so arranged that the coal was run into either oven as desired. Locomotive loading had not been so largely introduced into England, as might have been expected: chiefly because it was not economical to adopt the system in any yard containing less than 200 ovens, and possibly not even then unless the distances over which the small-runners were travelling was unusually long. He had no doubt also that the weight of the locomotives on the tops of the ovens had a tendency to shake the front-walls and to necessitate additional repairs to the brickwork; particularly as it was not generally possible to adopt Mr. Keighley's method of constructing the road, because in most English yards the main-flue occupied the position in which his tramway was placed.

Mr. Keighley was certainly to be congratulated on the output of his ovens—it appeared that 466,618 tons of coke were produced in 1900, and that if the works had been in operation full time 500,000 tons would have been produced. A ton of coke is calculated at 2,000 pounds, hence to compare it with English measure nearly 11 per cent. must be deducted from the quoted figures. But even then the statistics were somewhat remark-

able, as it would appear that in 1900 each oven produced 580 British tons of coke per year, or 11·1 tons per week; and that if worked full time it would have produced 621 tons of coke per year, or 12 tons per week. He (Mr. Greener) was quite aware that, in Durham, ovens of no greater capacity than those at the Oliver works were producing in some cases 13½ tons per week. The ovens he had in mind, however, were not ordinary beehive coke-ovens but were constructed with flues under the floor. There were doubtless others to which reference might be made also yielding more than 12 tons per week, but in every single instance he believed that they were burnt with hot air or fitted with other contrivances intended to increase the output. And, so far as he was aware, there were no ordinary beehive coke-ovens producing results equal to those mentioned by Mr. Keighley, and they were doubtless largely due to the high percentage of coke that he obtained and to the fact that the ovens were comparatively new and air-tight.

Mr. Keighley had also been able apparently to solve the problem of how to burn a beehive coke-oven in 24, 48, 72 and 96 hours as he chose. Such variations in the time of burning had not been attempted in Durham, or if tried they had not been successful. It would be interesting, therefore, to know the weight of the charge of coal and the quality and quantity of the resulting coke produced in a period of say 24 hours. It was not unusual for good coke to be made in 48 hours in flued ovens, but he (Mr. Greener) had not known it successfully accomplished in ovens of the beehive type, and he certainly was somewhat sceptical as to the quality of the coke that Mr. Keighley manufactured in 24 hours.

Many of the coke-burners in the local coke-yards were of opinion that, in order to obtain coke in the best possible mechanical condition, it should be allowed, as they describe it, "to soak in the oven" for 6 or 7 hours after it was burnt off. He did not for a moment believe in the theory: it was a very popular notion, but the practice was exceedingly wasteful, and it ought to be discouraged wherever it was in operation.

The yield of coke at the Oliver works was stated to be about 67 per cent. of the coal carbonized, fully 3 per cent. more than that usually obtained from similar ovens in Durham. He was well aware that 70 per cent. was in some instances realized over long periods, but in those cases the ovens were not of the ordinary bee-

hive type. An indication of the quality of the American coke might be gathered from the fact that it contained about 3 per cent. of breeze, from which he inferred that its mechanical condition was not so good as that of the best Durham coke.

The cost of manufacture did not strike him (Mr. Greener) as being in any way exceptional—it worked out to about 1s. 8½d. per ton of 2,240 pounds, and although that was doubtless a low working cost it was such as might reasonably be expected, having regard to the fact that the yard was constructed within the last 10 years and that special attention would certainly be directed to economy. He might add that the 9 feet seam of Connellsville coking-coal was very cheaply worked, as it was charged to the ovens at 4s. 4·1d. per ton calculated on the coke produced, hence the working-cost of the seam could not exceed 2s. 7·15d. per ton of 2,240 pounds. This result doubtless was possible at one time in Durham, but could not now be realized from the thin seams—many of them less than 2 feet thick—which are being worked for coke-making purposes.

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## DISCUSSION OF MR. J. McMURTRIE'S "NOTES ON THE FOREST OF MENDIP."*

Mr. F. W. Rudler (London) wrote that he had compared the plan attached to Mr. McMurtrie's paper with a copy of a similar plan preserved in the Museum of Practical Geology. This plan was inscribed as follows: "A Facsimile of an Ancient Document relative to the Mines of the Mendip Hills, in the Possession of Mr. Salmon, Holcombe House, Radstock, Bath. Copied, January 17th, 1846." This copy differs from the plan printed in the *Transactions*, only in trifling details; it did not, however, bear the signature "John Rowley." This document had, on its margin, engrossed in very small characters in brown ink, the Laws which are printed as Appendix I. to Mr. McMurtrie's paper,† beginning "Be‡ it right well knowne" down to the end of the tenth item.

There was also in the Museum a small rough copy of the same plan, with the addition of four sketches in the corners. These represented miners at work and miners' tools, and were identical

* *Trans. Inst. M.E.*, 1900, vol. xx., page 528.

† *Ibid.*, pages 533 and 534. ‡ Not "Bee" in this copy.

with the figures given on the upper margin of the printed plan in the late Mr. Robert Hunt's book on *British Mining*.* Mr. Hunt's plan, with the figures, appeared to be a reduced copy of a rough diagram, which, like the others, was formerly in the "Mining Record Office," under Mr. Hunt's care.

It will thus be seen that there are in the Museum of Practical Geology three copies of the plan attached to Mr. McMurtrie's paper, but they are all comparatively modern.

## DISCUSSION OF MR. H. D. HOSKOLD'S "NOTES UPON ANCIENT AND MODERN SURVEYING, ETC."†

Mr. H. D. Hoskold wrote that he desired to express his obligation for the sympathetic and considerate manner in which Colonel A. Laussédat had noticed and criticized his (Mr. Hoskold's) paper. No doubt every writer of any note possessed, or should possess, some speciality in science, and as a natural consequence would be likely to look at things generally from his particular standpoint. It should, therefore, be understood that the observations in his paper,‡ can only be taken merely as a passing reference to the existence, usefulness and importance of photo-theodolites, for "topophotography," etc., without describing or illustrating such instruments in a particular manner. It could not, therefore, be said that he (Mr. Hoskold) had designedly selected the best or the worst instruments of this class, and there was nothing to "astonish" the Colonel, because he (Mr. Hoskold) did not sufficiently bring forward the subject. Besides, considering that this gentleman affirmed that "there has been for some time a valuable literature upon the art;" it was not so imperative to give a general account of photographic instruments in connection with the use of a theodolite of a particular construction, in his (Mr. Hoskold's) paper. Apart from such considerations, a paper must have a limit, and what could be very well illustrated and fully described in a book, must, naturally, be curtailed when brought into the form of a paper. For these reasons, and considering that his (Mr. Hoskold's) paper was only intended to embrace the subject of the

* Page 134.

† *Trans. Inst. M.E.*, 1900, vol. xix., page 171; vol. xx., page 499; and vol. xxi., page 409.

‡ *Ibid.*, vol. xix., pages 210 and 211.

evolution of mine-surveying instruments, etc., and others, par ticularly and in general, other matters of interest were passed ove in silence.

His (Mr. Hoskold's) paper was not intended to introduce, fi and discuss the names of places in relation to their geographica position in South America, neither was Mr. Owen justified i raising a question of this nature which was altogether foreign t the subject treated. When the French king decreed that tw scientific commissions should be formed, in order that the firs should measure the length of a degree of the meridian near th equator, and the second near to the polar circle, Peru was selecte for the former operation, and geodetic operations were commence there in 1735 at, or near to Quito, and Cotopaxi, as previousl stated. All the authorities consulted upon this very interesting useful and important subject, agreed in following the example o the French, in placing Quito and Cotopaxi in Peru, at the perio named. De la Condamine, the chief of the French scientifi commission of 1735, published a book in 1745, entitled *Relatio of a Voyage made in the Interior of America Meridional*, and i it he mentioned that the French doctor, and attendant of th Commission, was murdered in the town of Cuenca, and in th documents of the legal proceedings which were carried on i 1739, the Spanish authorities stated that Cuenca was a city o Peru. According to modern geographers, this town is i 2 degrees 48 minutes 0 seconds south latitude, and Quit is in 0 degrees 13 minutes 0 seconds. He (Mr. Hoskold possessed a large collection of old maps of South America, includ ing the rare first edition of the Latin atlas of Ortelius, 1570, an others, all of which were used by him when writing his book upo the question of the limits, or proper boundary-lines which shoul divide British Guiana and Venezuela, and the Argentine an Chilian Republics; and no fewer than fourteen of these old maps by the best authorities, dating from 1610 to 1790, exhibited th northern boundary of Peru as extending a little to the north of th Equator, and placed the town of Quito a little southward of that line. It was, therefore, clear that neither the French com- mission, or other writers upon the subject, since 1735, had com- mitted any mistake in placing Quito and Cotopaxi in the then Vice-Royalty of Peru. The copy of the celebrated map of Lieut.- General Requena, 1790, in his (Mr. Hoskold's) possession, placed

Quito in the Vice-Royalty of Santa Fé; that of Lima to the south, and the Capitania-General of Caracas to the north and north-east; but the map did not define the limits of jurisdiction of the Vice-Royalties indicated. The map of South America, published by Cary in 1807, placed the town of Quito in the Vice-Royalty of New Granada, and clearly showed that the northern part of high Peru had been annexed to that jurisdiction. The large map of South America, by Arrowsmith, 1810, exhibits similar conditions. If Mr. Owen had completely studied the question that he had raised, and carefully taken into consideration the various changes which had occurred during and after the Spanish domination, according to their dates, he would not have confounded ancient possessions and limits with the present ones: and, further, he would have seen that he (Mr. Hoskold) was speaking in his paper of things done in 1735-1737, at a time when no South American republics existed. It was impossible to give in this brief reply a history of all such changes as had occurred in the limits and jurisdiction of the various districts occupied during the Spanish dominion until the formation of the various South American republics, neither was such a geographical notice, in an extended form, a proper subject for our *Transactions*.

# THE INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,
HELD IN THE ROOMS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE, LONDON,
MAY 30TH, 1902.

MR. J. S. DIXON, PRESIDENT, IN THE CHAIR.

## DISCUSSION OF MR. M. EISSLER'S PAPER ON "THE PRODUCTION OF COPPER AND ITS SOURCES OF SUPPLY."*

Mr. R. W. DRON (Glasgow) wrote, with reference to the Russian copper-ore deposits,† that the deposits on the Kirghese steppes, although known to be rich, could not be made available at present on account of the absence of fuel and the long distance to any smelting-works. There were several copper-mines in the Caucasus. In the Zangesursky district, copper-mining had been carried on since 1858, but it was only within the last few years that a properly equipped smelting-works was erected. The production from that district was about 800 tons of copper per annum. The cost of production was about £45 per ton of copper, this high cost being caused by the distance from which the fuel was brought, and the want of system in working the mines. The price of copper in Russia was about £70 per ton, so that there was an ample margin of profit. There were also smelting-works at Kedabeksky, owned by the Siemens-Halske Company, but, owing to the scarcity of fuel, these works were not employed to their full capacity. Copper-bearing veins had been found at several other points on the southern side of the Caucasian range, and were at present being prospected; and some deposits had recently been discovered on the northern side of the range.

Prof. J. WERTHEIMER read the following paper on "The Training of Industrial Leaders":—

* *Trans. Inst. M.E.*, 1901, vol. xxi., page 315.

† *Ibid.*, page 352.

# THE TRAINING OF INDUSTRIAL LEADERS.

By Prof. J. WERTHEIMER, B.Sc., B.A., F.I.C., F.C.S.

A comparison of some of our ways of dealing with technical education and those in vogue on the Continent and in the United States is supplied in a pamphlet* recently issued by the Association of Technical Institutions, of which the writer is the Honorary Secretary; and of necessity he will to a large extent make use of the facts there collected.

It may be convenient to consider separately the two modes of technical training which are available in this country at present, namely:—(1) Training for those who enter the industries early and gain their theoretical knowledge and laboratory-experience in evening classes, and (2) training for those who enter the industries at a later age, having previously prepared themselves by attendance at day-courses in technical colleges.

(1) There can be no doubt that for the man who is to occupy a post as a skilled artizan and who does not intend or need to obtain for the purposes of his daily work a deep insight into the scientific or artistic foundations on which his industry rests, evening classes may satisfactorily provide all that is needed. And we may congratulate ourselves that in respect of the provision of evening classes for artizans we are in an exceedingly favourable position in the large towns of Great Britain; and we can boast of an enormous attendance at such classes. Unfortunately, however, the great majority of our evening students fail to reap the full benefit of these classes either for themselves or for the State, which bears the cost of them; and one reason for this is that a large number of the students come to the classes in an unprepared state, having left their day-schools after very imperfect preparation. Partly as a result of this and partly, perhaps, because some artizans who get their teaching for next to nothing value it at the price which they are asked to pay for it, comparatively few evening students

* *Are our Industrial Leaders Efficiently Trained? A Comparison of Technical Education at Home and Abroad*, Bristol, 1901.

pursue their courses for a sufficiently long period to enable them to obtain an amount of knowledge likely to make them of greater service either to their employers or to the nation. Still, notwithstanding these drawbacks, evening classes in science, art and technology have greatly helped to increase the efficiency of our artizans and have provided the best of them with the means of rising to positions of greater responsibility. Indeed, not a few of the industrial leaders of to-day, and possibly some of those whom the writer has the privilege of meeting here, have obtained in evening classes their first introduction to the sciences upon which rest the improvements that they have introduced into their work.

If this be so, it will naturally be asked why we should be alarmed if our day technical teaching is not on as sound a basis as that of our competitors. The answer is that what was good enough twenty or thirty years ago is not, necessarily, good enough now. The world has not stood still in the interval: Germany, Switzerland and the United States have made marvellous strides in industrial matters. We need not copy their methods slavishly; but we shall be foolish if we fail to examine educational methods on which each of these countries has spent enormous sums of money in the belief that thereby its industrial progress has been greatly accelerated. We must also remember that in this country apprenticeship is no longer what it was; there is so much more to learn in every industry, and the masters and their principal assistants are so much busier, that they have less time than ever to teach it.

(2) We come, then, to the need for technical training for the higher industrial posts; this must be given mainly, though not, of course, entirely, in day-classes and should, as a rule, precede entry into industrial life. It should be accepted in place, not of all, but of some part of a young man's apprenticeship in a workshop, a mine, or wherever his sphere of action may lie. This, unfortunately, is not fully recognized in this country, though each year a small, but increasing, number of employers is willing to reduce the period of apprenticeship in the case of men who have had a thorough college-training. In America and in Germany, the case is otherwise, and employers in the engineering industries are willing to accept from trained students a much shorter apprenticeship than is asked in the case of untrained men. In this way, they, at once, recognize and foster proper technical training.

How do we stand in this country as to provision for such training? What number of day students are taking organized courses of technical instruction in the day-time in Great Britain and Ireland? Last session we had in all industries taken together 3,873 students. How does this compare with Germany? In nine German technical high schools, alone, there were over 11,000 students, not counting—as we have done in the British figures—the special schools for agriculture, forestry, mining, etc.

But you will say rightly that mere numbers prove nothing; what of the relative ages and previous training of British and German students? Firstly, as to age: we could only obtain our 3,873 students by counting all day technological students in this country who were over 15 years old; none of the German students were under 18. Secondly, as to previous training: in most of our technical colleges there is either no entrance-examination or it is an extremely easy one; in the German schools it is the exception for any student to be admitted unless he can produce a satisfactory leaving-certificate showing that he has completed with credit a nine years' course in a secondary school. So that, as far as age and previous training are concerned, British students are far behind those of Germany. The conditions in the United States are similar to those prevalent in Germany.

Still, it might be supposed that our students, by prolonged courses of study, made up for early age and imperfect preliminary training. The contrary is, unfortunately, the case. Take engineering: we had in the whole of this great engineering country only 347 third-year and 52 fourth-year students, making 399 in all. In a single German technical high school (Charlottenburg) there were more, namely, 477; and our 399 includes some students as young as 17, and many of only 18, while all these Charlottenburg students were over 20, and more than half over 21.

You will ask, what are the prospects of young men who have been trained in these foreign schools, and who leave at the age of 22? Let us base our answer on actual facts taken from the statistics of an American institution, the magnificent Massachusetts Institute of Technology at Boston. This college is much better equipped than any similar institution in London, a city many times larger. Its staff is much more numerous than that of the best London technical college, namely, the Central Technical College at South Kensington. For engineering there are at Bos-

ton 87 teachers, of whom 24 are regular professors; at the Central Technical College there are 22 teachers for engineering, of whom 3 are regular professors. The number of day-students—all over 18—at Boston exceeds the total number of day-students of technology over 18 in the whole of the United Kingdom. Each year about 300 of the students—all over 22—leave the institute after completing a four years' course, and the American employers value the training so highly that every one of these students is provided with an engagement before he completes his course.

The sums of money spent on higher technical education in this country are contemptible, when compared with the amounts provided for the same purposes in either the United States or Germany; and the latter is a comparatively poor country. We must, therefore, either believe that our astute American and German cousins are foolishly wasting the time of their young men and much hard-earned money on unnecessary technical training, or that we are wofully negligent in the matter of equipping ourselves and our children for the commercial and industrial struggle which has already begun, and is likely to become increasingly severe.

Hitherto we have dealt with the general question of technical training as it affects all our industries; let us now see how the matter stands in respect of the industry with which The Institution of Mining Engineers is primarily concerned. The writer is indebted to Dr. Harris, Commissioner of Education for the United States, for supplying the latest official figures as to the number of American day-students taking academic courses in preparation for the various industries; for mining the number is 1,261 for the session 1899-1900. The corresponding figure for Great Britain and Ireland for the same session was 166,* or less than one-seventh as many as in the United States. The relative importance of the coal-mining industry in this country and the United States may be estimated by the following figures, giving the coal raised in each in the year 1900:—Great Britain and Ireland, 228,794,919 metric tons: and the United States, 244,901,839 metric tons.† Let us next compare our figures with those of a single mining-college

* This number only refers to coal-mining, and it does not include students of metallurgy.

† *Mines and Quarries: General Report and Statistics for 1900*, page 303.

in Germany—the Royal Saxon Mining College at Freiberg. Last session there were in this single institution 372 students, or more than twice as many as in the whole of the United Kingdom. In the German Empire in 1900, 149,788,256 metric tons of coal were raised, as compared with our 228,794,919 metric tons.*

Of our students, 118 were first-year students and 29 were second-year students; there were only 15 third-year and 4 fourth-year students.† This means that only a very small number of our students spent sufficient time in study to enable them to obtain a knowledge at all comparable with that of the American or German mining students; moreover, we must note that most of the foreign students begin their studies at a later age than ours, and are not admitted unless they can show that they have received a thoroughly good general secondary education. In fact, in a single American institution, namely, the Michigan College of Mines, there are more day-students taking complete courses than in the United Kingdom; for the Michigan college has 178 students, of whom 76 are first-year students, 60 second-year students and 42 third-year students. In all our institutions we have less than half as many third-year students as there are in this single college in the United States.

As a result of the facts just mentioned, the courses of instruction for mining-engineers in Germany and the United States are of a much more advanced character than those which it is possible to give in this country. A minimum period of three years' study is required for a diploma, and in Germany the higher posts in the industry are open only to those who hold such a certificate. In this country we have nothing to take the place of such a diploma except the mine-manager's certificate, the standard for which is low when compared with a German diploma. The State, therefore, offers no inducement to young men to fit themselves in the best way possible for their future career; nor does it seem likely that it will move in this direction, until The Institution of Mining Engineers declares that our young mining-engineers shall be as well equipped with scientific knowledge as their German and American colleagues. No doubt the mine-manager's certificate

* *Mines and Quarries: General Report and Statistics for 1900*, page 303.

† These figures only relate to students of coal-mining, and they do not include students of metallurgy.

meets the case of a subordinate official in a mine, and it should be called a "mine-foreman's certificate." But surely much more should be required from those who are to be actually responsible for directing and supervising the great mining-industry of our country.

As an illustration of what is required in Germany, it may be mentioned that the diploma of mining-engineer at Freiberg is gained only by those who can show that they have received a good general education up to the age of 18, and have subsequently acquired a sound practical and theoretical knowledge of mining, surveying, machine-construction, chemistry, electrotechnics, physics, mineralogy and geology, as well as a knowledge of higher mathematics, descriptive geometry, and the mining laws of Saxony. The requirements in such excellent American institutions as the Michigan College of Mines at Houghton are of a similar character.

These foreign mining-colleges are much better equipped than any similar institutions in this country, and the teaching staff is more numerous and contains more specialists. Thus, at the Michigan College of Mines, the teaching staff numbers 23, or one for each set of eight students; there are five professors, namely, one each for physics and mechanics, chemistry and metallurgy, civil and mining engineering, mechanical and electrical engineering, and geology. There is an assistant-professor of mathematics and physics, and there are instructors and assistant-teachers in the above subjects, as well as special instructors in petrography, machine-shop work, mineralogy, mine-surveying, etc.

The mining-industry is one which has, as yet, felt but slightly the pressure of foreign competition. The same might have been said at one time of our iron-industry, which is now slowly but steadily yielding to the inroads of foreigners; thus in 1899 we produced over 9 million tons of pig-iron; in 1900 less than 9 million tons, and last year only slightly more than 8 million tons. In the United States, the production was in 1890 a little over 9 million tons; in 1900 it was over 13 million tons, and last year about 16 million tons. A considerable part of this increase is due to the improved methods which the superior technical training of American metallurgists has led them to adopt.

From all parts of the United States one hears of the rapid

introduction of machinery into coal-mines. Mr. J. E. Roderick, the chief of the Bureau of Mines for Pennsylvania, informs the writer that "machinery is largely used in the States," and Prof. F. W. McNair, the President of the Michigan College of Mines, states that "machinery is very largely used for coal-mining in this country." Here its use is much more rare; Mr. Bennett H. Brough in his paper in the *Nineteenth Century*,* states that by the use of machines in America the output per miner is increased from 50 to 100 per cent. Moreover, both in America and in Germany, minerals are, in some cases, being worked at a greater depth than in this country. Superior technical training might help us to see our way to win coal much more economically than we do at present, and so maintain our position as a great coal-producing country. It rests in the end with the members of The Institution of Mining Engineers to say whether or not they will encourage such training. Our young men are, the writer believes, more than equal to their foreign competitors; but as regards their intellectual armanent, they carry pop-guns to meet the rifles of the Germans and Americans. It is in your hands to alter all this; it may mean an increase in salaries, but increases in salaries, judiciously made, lead to still larger increases in profits.

Finally, the writer ventures to quote the words in which Prof. V. C. Alderson, Dean of the Armour Institute of Technology, Chicago, ably sums up the present situation of technical education in this country, the United States and Germany:—

> London has received no greater shock recently than to wake up and find that the equipment of the new "twopenny tube," as the underground railway is called, was almost entirely American. The error which Englishmen make in the field of technical education is a failure to recognize the difference between the skilled workman and the professional engineer. She has been endeavouring to compete with the highly trained scientific experts of Germany and America by simply educating the hand, training artizans in the belief that she was making professional engineers. Not until England is dotted with large and flourishing schools like the Central Technical Institute of London, not until the English realize the necessity of training both the hand and the head, and not until she perceives the full value of high-grade engineering education will she be safe from the intrusion of German and American engineers who have had a thorough engineering training.
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> It is patent even to the casual observer that the present industrial eminence of Germany is due to her fostering care of technical education. The alarm felt in England over the threatened loss of her supremacy is undoubtedly due to her general neglect of this same subject. To be sure, the Germans are excessively

* 1900, vol. xlvii., page 668.

theoretical and visionary, traits which are reflected in her schools; the English, on the other hand, depend too much on mere shop-practice, unfortified by scientific training. The middle ground is undoubtedly the better one. That is the position taken in the United States to-day. More theoretical than the Briton, more practical than the Teuton, the American can in efficiency excel either. This characteristic is also reflected in our technical education. Our schools teach the scientific basis of engineering better than the English do and the practical application better than the Germans.

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The Rev. H. PALIN GURNEY (Newcastle-on-Tyne) wrote that his experience of evening classes did not justify his unqualified concurrence in the opinion expressed by Prof. Wertheimer that these provided satisfactorily all the training desirable for skilled artizans. Young men were often weary with a long day's work and too exhausted to retain sufficient alertness and receptivity of mind to do justice to themselves or their instruction, and employers should consider seriously the importance of allowing their apprentices ½ day per week for their studies during the session, on condition that they also attended evening classes at least once a week. The subjects of study should be carefully arranged, so as to continue and supplement the teaching that they had received at the elementary schools. The course should be continued for at least three sessions, perferably five. The afternoon should be considered part of their work and the foremen under whose charge they are placed should be directed to give suitable encouragement to the diligent. He believed that employers would find such an arrangement to be a remunerative investment.

It was well known that the technical training demanded by employers from candidates for higher industrial posts in this country was very inferior to that found advantageous by other countries who were competing with us in commercial enterprises. The average Briton thought very little of the importance of intellectual training. He relied on his energy, his capacity, and his perseverance to do what needed doing, and what was the best way of doing it seemed to him of secondary importance, as he considered that it was sufficient to set to work with the determination to succeed. The position was intelligible. Circumstances had developed in Britons a practical capacity which had led them to inventions and industrial movements which had revolutionized the world. Other nations had now profited by our experience, and while we were inclined to remain contented

with our original methods, they had seen the desirability of increasing their capacity of production by taking advantage of the latest discoveries of modern science. We need not fear competition if we were willing to adapt ourselves to the altered circumstances of the commercial world, which we ourselves had largely brought about. But it was necessary for us to cultivate our powers of observation and deduction, and to add to our store of knowledge. No man should expect to rediscover everything for himself; and, even if he could do so, it would be handicapping himself, to neglect the results of the labours of other men. The country most productive of commodities useful to the world would acquire most wealth. The nation which exhibited the greatest facility in supplying the necessities of mankind and in improving most successfully the conditions of life would become the greatest and the most powerful. Education would develop the energies of a people, and direct them in the way in which they could be employed most efficiently for the public good. It cultivated the judgment, so that men were enabled to realize the conditions of the problems brought before them and to do what had to be done as well as possible and, if possible, better than it had ever been done before. We needed not only experts to make discoveries, but also managers quick to perceive the bearing and the possible applications of the most recent inventions, and workmen sufficiently intelligent to carry out their instructions so as to give improvements their best possible chance. But we must look to the efficient training of the leaders of industry for maintaining our position in the keen commercial competition among the nations of the world.

Mr. J. Gerrard (H.M. Inspector of Mines) remarked that the stated number of 166 students in this country must evidently be an error. Perhaps it only took cognizance of the Royal School of Mines, and if so it ignored what was being done in Newcastle, Glasgow, Cardiff, Wigan, Leeds, Sheffield, and other districts. He would like to know on what grounds the author stated that both in America and Germany coal was being worked at greater depths than in this country. Certainly as regards America, any one acquainted with the question must have been struck with the shallowness of the coal-mines which were being worked; and he very much doubted whether in Germany coal was

being worked at any greater depths than in this country. With reference to the qualifications for a mining-manager's certificate, it had been recognized in this country that book-learning did not qualify the charge of men and the charge of a mine; but that it was necessary to have a very close, practical acquaintance with all the complicated features of coal-mining, and the State had said that that experience shall extend to 5 years. As to the question of 5 years experience in or about the mine, the time had arrived, when that should be revised, as it had been found to form a very serious difficulty in arranging for technical instruction. There were two classes of officials engaged in mines:—(1) The sons of owners and others, and (2) the sons of managers and under-managers, mine-officials and workmen, who could not give the large amount of time involved in 3 or 4 years solely devoted to technical education, either before or after their acquaintance with the practice of mining. His own view was that there should be some provision for gaining practical experience in mines along with technical education. They could learn much from their American neighbours, and it was certainly true that the Americans had learned much from us, for we had shewn them the way in many particulars, especially in connection with coal-mining.

Prof. Henry Louis (Newcastle-upon-Tyne) said that he had written a paper, a few years ago, on the subject of technical education, and pointed out, as the author of the present paper had done, that in America and Germany the facilities for technical education were distinctly better than in this country. In the interval, various things had happened; then Great Britain was the leading coal-producing country, now America had taken the lead, and we should probably not regain it. Quite recently, German mining-engineers had come over to this country to carry out a difficult piece of sinking, based on scientific methods, that we were either not able or did not care to undertake. This was a complete reversal of what used to exist, and depended entirely upon scientific progress. It was, nevertheless, a mistake to imagine, as the author seemed to do, that we were standing still; for example, during the last few years, the number of chairs in mining had nearly doubled, several new lectureships had been founded, and the attention paid to technical mining education was on the

increase. He joined issue entirely with the author, who stated that we had nothing to take the place of the German diploma except the mine-manager's certificate, for there was besides the bachelor-of-science degree in mining granted by Durham University and others, the Royal School-of-Mines certificate, and other similar degrees or titles. He entirely disagreed that foreign mining-colleges were always better equipped, or that the teaching there was on a higher plane than in this country. The arrangements for the professorships and the chairs held in this country were practically identical with those abroad, and the opportunities afforded here were as good as elsewhere, so that men had every facility for learning, and he had little hesitation in saying that the students who left our universities and similar institutions could be as well equipped as those from Germany or America. It was perhaps pardonable egotism to state that a student from Durham University went over to Columbia College, and carried off the highest honours there in metallurgy. No doubt, the author was quite correct in pointing out that there were fewer students in this country than in Germany or in America, though the figures which had puzzled the last speaker probably referred only to those who were taking the full bachelor-of-science course—the course which leads to a diploma. The reason why students did not always take this course was also obvious; it was because the law would no longer allow time spent in acquiring scientific knowledge of mining subjects to count as a qualification towards the colliery manager's certificate. As the law stood, at present, any man working in a mine had a preferential right to sit for his certificate, and if he could manage to pass the examination was justified in doing so, while the man who had spent 2 or 3 years at college, and another 2 or 3 years in a mine, was not. What stood in the way of mining education in this country was the discouraging condition of our mining legislation, and so long as the law compelled a man to pass 5 years underground, before he could qualify to earn his livelihood, so long should we have this difficulty and be confronted with the deficiency in the number of mining-students in this country. It simply meant that there were comparatively few men who were in such a position that they could afford to spend the 3 years required to obtain their college or university training, and another 5 years in addition underground, before they were justified in applying for a manager's certificate. He did not say

that a man who had had only 5 years underground was qualified to take charge of a mine for that reason; but the law ought to discriminate between the man who came to pit-work without having his mind prepared by previous study, and the man who was thus prepared, with a basis to go upon, and merely wanted to learn the practical applications. A student, who had done his scientific work properly, could acquire as much in the pit in 3 years as the untrained man could in 5, and until we got legislation on that basis we should remain very much where we were. One reason why in Germany there were so many mining-students was, that there such a training was a necessary step to an inspectorship of mines. There inspectors were more numerous, and for one thing they had wider and different duties. In Germany, the State took a royalty on minerals, and it was the duty of the inspector to act as viewer for the State. So, unless a man had gone through the prescribed university career, and won his diploma, he could not be appointed. He (Prof. Louis) believed he was right in saying that, of all the inspectors of mines in this country, only one (now retired) was trained at the Royal School of Mines. This at once pointed to the great difference in our method of doing things. He was not now so much finding fault with the English method, as pointing out the greater inducement for the Germans to go through their course of training than there was here. The position of mining legislation seemed the more absurd and anomalous when it was remembered that we had a Royal School of Mines, supported as a public institution; and presumably the State, in supporting it, believed that it was training men for some use in the mining industries of the country, but instead of this being recognized the proposition was laid down that men so trained were no better than any ordinary men in the pit, and that they must put in their time there just the same. If mining training was of no use, why had we a Royal School of Mines? and if it was of use, why was it not recognized? He thought that these were some of the chief grounds for the differences between English and foreign methods of education, but he did not think that we were so far behind in our educational facilities as the author wished to make out.

Mr. Bennett H. Brough (London) said that the two previous speakers had made it so clear that defective legislation was the

principal cause of the drawbacks to which the author of the paper had drawn attention, that it was not necessary to dwell further on the subject. It was a matter of some surprise that the paper had not referred to the fact that in this country the system of training industrial leaders by articled pupilage was the recognized British system, and though it had probably certain defects, yet the experience of that system had been such as hardly warranted the suggestion that we were so far behind our American and German friends as the author implied. If the figures in the paper referred to the number of day-students attending mining-classes in Great Britain and Ireland, there must be some error. He had not the figures for London, Newcastle, Cardiff, Leeds, Birmingham, Glasgow and Dublin, at all of which places there were professors of mining, but he had recently had an opportunity of examining the plans drawn by the students at Camborne, where alone the mining class numbered 85. If these were included in the figures mentioned by the author that would leave only about a dozen each for the other institutions. Then, as regards the figures given for America, the author included in his total the students who were learning such subjects as architecture. At Freiberg, the number of 372 students was quite abnormal: when he was there the number was less than half, and it must be remembered that they were not all going in for mining, but were studying other branches of engineering, civil, electrical, etc. Freiberg was a metal-mining centre, and coal-mining students were rare. Of the 372 students mentioned, only 156 were German, so that a large proportion were foreigners, many of them being English, a factor which was not taken into account in the paper. As regards the Michigan College, which had been mentioned in eulogistic terms, he had the opportunity of visiting it in 1890. Like the Camborne school, its analogue in this country, it was undoubtedly doing useful work. Its building was, however, referred to in 1897 by Dr. M. E. Wadsworth,* the president of the college, as a "hovel;" certainly the equipment was distinctly meagre, none of the professors were over 30 years of age, they received very small salaries, and gave up their professorship as soon as any opening in practical work presented itself. The equipment of the German schools was not, he

* *Transactions of the American Institute of Mining Engineers*, vol. xxvii, 1898, page 716.

thought, to be compared with the schools of this country. When he was a student in the Clausthal School of Mines, in the Harz, there was, for example, no gas in the assaying laboratory. It was mentioned in the paper that the production of pig-iron in the United States exceeded that of this country, and this was attributed to the advantage taken there of the better technical education afforded. But there were other questions which would have to be taken into account—economic questions, such as the supply of raw materials, free trade and protection, and other disturbing factors. In his own experience of American engineers he was not struck so much with their superior technical knowledge, as with their remarkable versatility. He had had the pleasure of knowing American mining-engineers who at different periods had filled the positions of milkman, timberman, clerk and bank-manager, and they seemed to be able with their quick grasp of new subjects to change rapidly from one branch to another without the slightest difficulty, and certainly many of the most successful mining-engineers in the United States had not received any college-training. An illustration of this was afforded by the phenomenal success which had attended the Scranton Correspondence School of Mines, which had students all over America; the success which had attended that institution showed with what keenness American mining-engineers made up the existing defects in their technical education. The quotation from Prof. Alderson at the end of the paper might be looked upon as a very delicate advertisement; in that light only could they also look at the remark that all the students of the Massachusetts Institute of Technology were provided with an appointment before they had finished their course. He was sure that the writer underestimated altogether the value of the results which he (Prof. Wertheimer) and other distinguished teachers had obtained in different parts of this country.

Prof. ARNOLD LUPTON said that there could not be any doubt in the minds of those who had travelled on the Continent and in the United States, as to the prestige of professors in those countries as compared with our own. It was only quite recently that the position of a professor in England had become one entitling the holder to any respect at all, the idea being that if a man was qualified to give a lecture on any subject he must be ignorant of

everything else, but thanks, no doubt, to such men as Prof. Louis and others, and also to the foreigners' example, we were beginning to attach some respect to a professor. He, himself, was occasionally called professor, though it was some time since he had had the honour of being one. No doubt every engineer who took a pupil would rather have a bachelor of science as a pupil than an ignoramus. They need not follow the sheep-like process of class-training, nor should they follow that of leaving the students to themselves, while the professor was engaged in some course of research which no doubt would add to his own reputation. Many of the inventions imported from foreign countries referred to in the paper were due to the circumstances of the case: new methods of sinking, for instance, such as the Kind-Chaudron and the freezing method; how was it that some of these methods had been carried on for at least 40 years on the Continent? It was because on the Continent there were difficulties to be overcome which did not exist in Great Britain. There had been very few cases where the freezing method was necessary in this country, and the adoption of these methods on the Continent only showed that the French and others had the same faculty that we had for finding means to meet the difficulties which arose. Nearly all coal-cutting machines had been invented in Great Britain, though no doubt they had been re-invented abroad; but he thought it would be found that the engineers of this country were practically the pioneers of coal-cutting machinery. He was not one of those who thought that the educational facilities of foreign countries had necessarily equipped the foreigner with any great advantage over us. He thought that we still maintained the front rank in coal-mining engineering, and that we would keep abreast with the best; but our difficulties were increasing, and with the increased difficulties would come an increase of skill and inventiveness to meet them. With regard to the Government certificate of competency to manage a mine, when it was proposed 30 years ago to have those examinations, he was one of the very few who opposed the system, maintaining that it was impossible to gauge a man's capacity for managing a mine by any examination. He was still of the same opinion, but he did not think it did much harm because it was so easy and elementary in its nature that a good practical man could generally obtain his certificate after two or three tries. Some men could not pass an

examination, and there were some good practical men actually in charge, while somebody else with a certificate was nominally so. In some districts, the conditions were much more stringently enforced than in others, for while in some cases a man must prove that he had been engaged for 5 years in the pit, in another it was taken to be sufficient if he had served 5 years with a mining-engineer, some of which time might have been at the college; but he thought that the less they interfered with the mine certificate the better it would be for the managers of mines. He was certainly in favour of an university degree counting for at least 2 years out of the 5 years, as this would undoubtedly be better than 5 years down the pit without the college-training. At the same time, that did not prevent him from supporting the author in his desire to see British colleges fitted up in the best possible manner, and with the best professors at adequate salaries.

Mr. Sydney F. Walker (London) remarked that the scarcity of labour in America was one reason why they had developed an extraordinary capability for devising machinery, and it was also found there that the workmen were less bound by stringent trade-union regulations. Then too, while a British workman would only look after one machine, the American would watch three or four. He thought that education in mine-engineering had largely freed itself from the trammels with which technical education in electrical work was still fettered, for the technical colleges did not give them a thorough insight into practical work which would enable the student to detect even the simplest faults. He instanced a case in reference to a telephone, which had become useless because a lever did not make a proper contact, and said no college text-book contained such instructions as would lead to the discovery of such a fault. The successful men were those who knew the theory thoroughly, but who also were fully qualified in the practical application for it. He thought that in our British technical colleges the work of the professor was often too varied, and it was desirable that there should be one man for each separate branch of a subject and that he should specialize in it.

Prof. Carus-Wilson (London) said that he had had the privilege of being a member of the staff of a large technical college in Montreal, Canada. His own department was electrical engineering; in his experience, manufacturers in America heartily wel-

comed students who had graduated from technical colleges; and fully appreciated the power which their technical training had given them to meet the practical difficulties of their profession as they occurred, but of course these practical difficulties could not be solved in the college. It would be of immense benefit if anybody could devise a proper method for the preliminary training of boys intended afterwards for the technical institutions of this country: it was most difficult to find the proper course to which boys should be put before sending them to technical colleges; it was useless to attempt improvement only at the top of the ladder, it was on the lower rungs that they must look for improvement. One great feature of colleges in the United States and Canada was that one professor dealt with one subject only, and he thought that their example in this direction might be followed here.

Prof. R. A. S. REDMAYNE (Birmingham) wrote that there had recently been established at the University of Birmingham a faculty of commerce, under the guidance of Prof. W. J. Ashley, who had had considerable experience of American institutions and methods of instruction, seeing that he was at one time professor of political economy and constitutional history at Toronto University, and, until a year ago, professor of economic history at Harvard. Those who were interested in the subject of commercial education could not do better than obtain from the secretary of the Birmingham University the pamphlet which Prof. Ashley had written on the subject,* and also the outline of the curriculum and regulations in connection with the same. The Birmingham University was the first, and only, British university that had established a faculty of commerce; and he hoped that it would prove so successful as to induce the universities situated in other large commercial centres to emulate its example. Prof. Ashley, who had just returned from a visit to Germany, where he had been studying German institutions and methods of instruction, stated that, until 4 years ago, all that was being done in that country in the way of commercial education, although valuable in itself, was on a comparatively low level, was, in fact, practically the education of clerks, and not of principals, managers, directors of business, etc. Recently four institutions had been created for much higher commercial

* *The Faculty of Commerce in the University of Birmingham: Its Purpose and Programme.*

education, but of these, two, including the most promising, were only one year old. So that, really, the movement was in almost as experimental a stage in Germany as in England.

There was a great danger lest the methods that had been used for commercial education of the lower type should be imported into the new institutions, which should aim at an instruction differing not only in quantity but in quality. But leading men were aware of this danger, and one of the most interesting features of the German situation was that a good deal of what may be called "first-class thought" was now being directed to the problems of curricula and methods of teaching.

Another point of interest, was that the new ventures, notably those of Frankfort and Cologne, had been started on a scale incomparably greater than anything which had hitherto been regarded as practicable. Each of these schools began its work with a staff of eight professors giving their whole time to the work, together with a score of experts, officials, judges, and others in the neighbourhood giving short courses of lectures.

As he (Mr. Redmayne) had been for some time enquiring into the methods of teaching pursued in the mining departments of the leading technical institutions of Canada and the United States of America and the nature and extent of the equipment, laboratory and otherwise, and was on the point of paying them a visit of inspection, he was much interested in and agreed with what Prof. Wertheimer stated as to the superiority of these mining-colleges as compared with British mining-schools.

As British law at present stood, with respect to coal-mines, a mine-apprentice was obliged to have had 5 years' actual underground experience before he could enter for the examination for the certificate of competency to manage a coal-mine. Consequently, few young men after leaving school could afford the additional time (say 3 to 4 years) requisite to take a mining degree, making 8 to 9 years in all. The result was that we, in Britain, were not turning out mining-engineers who were in a position to compete with those of Germany, and, more especially, with those of America, in point of knowledge as well as in experience; namely, men who brought a trained mind to bear upon their work. If a mining degree, acquired after, say, a 3 years' course of training in a mining school were allowed by the Government to count for 2 out of the 5 years necessary apprenticeship, he felt

sure that it would be the means of producing a class of mining-engineers far better equipped mentally for their duties than were many of those of the present day.

The time of the mining-students at an university should not be devoted specially to theoretical work; much of it should be of an intensely practical character. There should be weekly visits to the mines of the neighbourhood, and 4 or 5 weeks should be devoted by the students each year, in company with the professor, to the inspection and study of some group of metalliferous mines in Britain or abroad. He suggested that before entering upon a course of study at a mining school, intending university mining-students should devote one year of their mining apprenticeship to practical work at the mine, as it had been shown by repeated examples that young men who had some practical experience of the mining profession before entering upon the scholastic part of their professional training, more clearly perceived the necessity for and value of the scientific training required to fit them for it, and, therefore, pursued their studies with greater zest and more satisfactory results. At the same time, we should be in a position to place before mining-students educational facilities in point of equipment equal to those of American mining-colleges, if we intended them to pursue the higher technical training adopted in that country.

Prof. WERTHEIMER, replying to the discussion, stated that the figures quoted in the paper were collected from the authorities of all the technical colleges of England, Scotland and Ireland; only those relating to coal-mining were given, and he thought that if the metallurgical figures were added the total would not be more than doubled. As they stood, they represented the total number of students of coal-mining in Great Britain and Ireland. Referring to Prof. Louis's remarks, the students both in Germany and America started on an altogether higher level than in Great Britain. At Newcastle, there was an excellent college, which a boy could enter at 16, or earlier if they could pass certain examinations; and this was at least 2 years younger than was the case in America and Germany, with students who sat for their diploma. At Freiberg, the mathematics with which the students commenced were not far below those with which they finished at Newcastle, for they required the students on entering to take differ-

ential and integral calculus. Nor was it the case that our institutions were as well equipped as those abroad, while they would not at all compare in the matter of space occupied or the amount of money spent upon them.

As regards the depth of working the mines, he did not intend to convey the impression that mines were generally worked at greater depths in America and Germany, but the figures as to the depths of some of the deepest mines of the world would bear out the statement made in the paper.

The PRESIDENT said that deeper mines than those worked in England were metalliferous: we were now dealing with coal-mines only, in which this country certainly had the deepest, except one or two on the Continent.

Prof. WERTHEIMER said that, as regards the thoroughness of the teaching in British colleges, he was quite sure that the professor of mining-engineering could be relied on to teach all that a mining-engineer needed.

Referring to Mr. Brough's criticism, the latest figures showed that there were comparatively few Englishmen at Freiberg at present: Mr. Brough's statistics were unfortunately antiquated, and the "hovel" at Houghton, Michigan, had developed into an institution such as they in England might envy.

As regards the production of pig-iron, he did not, of course, mean to state that the development of the pig-iron industry in America was entirely due to technical education, but only that the leaders there considered this an important factor.

It was no doubt true that many successful mining-engineers had not had a technical training; and this was a stock-argument with those who began their professional life 20 or 30 years ago when there was far less need for technical knowledge. A prominent boot-and-shoe maker in Bristol some years ago said he did his work exactly as his grandfather and great-grandfather had done, and he did not know what they wanted with technical education; but if all the boot-manufacturers of Bristol had taken that view, they would not have been so well able to meet foreign competition as they were to-day.

He would be sorry if it was thought that the remarks on the Massachusetts Institute of Technology were used in the form of an advertisement; they were facts stated in a private letter to

Mr. Mather, of Messrs. Mather and Platt, and he was sure that the President was too wise to guarantee employment for all his students.

He did not under-estimate what had been done in Great Britain for technical education, and he believed all that was possible was being done with the very limited means at present at our disposal, but what we were doing was trivial compared with what was being accomplished abroad. One department of the Berlin Technical College was as large as a whole college in this country. The status of a professor abroad, too, was very different; many of them were Privy Councillors, and they were taken into the confidence of the Cabinet. They were also more closely in touch with the industries than here, where any similar arrangement could only be possible by a very large increase in their numbers.

As regards practical work, the student nowadays did come in actual contact with apparatus, though the apparatus was not necessarily on a commercial scale; and he was encouraged to solve his difficulties as far as possible. Certainly a young man who was going to develop into an efficient engineer would be none the worse for knowing the theories which he would have to put into practice; and, if he was at all intelligent, he would know that a theory was not a thing to be worshipped, but to be used wisely. Many of his former students were engineers in charge at central electric-lighting stations; they could not be merely theoretical persons, or they would not be long there.

He quite agreed with Prof. Carus-Wilson that our system of technical-college professorships needed remodelling. At the Technical College at Berlin, in electrical engineering work for instance, they had one professor dealing with central-station work; another with traction-work; another with telegraphy and telephony, and so on; in all about five or six professors with an adequate number of assistants, each and all being in contact with the industries. Under our present system educational work was so poorly paid that a man who had the necessary qualifications could as a rule earn far more in the industry, and he did not quite see how that difficulty was to be solved. The best men would certainly drift off into the industries, until we rose to the point of attaching sufficient importance to education so as to cause us to give adequate salaries.

He believed the remark of Prof. Louis touched the whole matter, when he said that the trouble was in defective legislation. Some three years ago a committee, consisting of Prof. Louis, Prof. Galloway, Prof. Le Neve Foster, Prof. Hardwick, and others, including himself, laid before the Council of The Institution of Mining Engineers a proposal that the State should be asked to recognize a college-certificate, not as doing away with the mine-manager's certificate but as something higher at which the student might aim; and what they particularly asked the Council to do was to join with the various colleges in pressing upon the Government the desirability of accepting a certain amount of college-training as the equivalent of a certain amount of underground work. Supposing that 3 years of college-training were accepted in place of 2 years underground, a further 3 years would be sufficient, he believed, to give the necessary training to ensure that the student became an efficient mining-engineer. This was being done in Germany and America, and he hoped that (as the outcome of this paper) the Institution would make some move in that direction.

The PRESIDENT (Mr. J. S. Dixon) said he entirely agreed that it was desirable that time passed at a technical college should be taken as part of the curriculum for a colliery-manager's certificate. In his own district, there was a difficulty with miners' unions who were convinced that H.M. inspectors of mines and mine-managers should be selected from the miners themselves, and they took every opportunity of pressing those views forward. While he agreed with every word which had been said as to the advisability of colliery-managers and engineers having a thorough technical and scientific education, he might say that in the matter of handling men and work a colliery-manager was born and not made. But, of course, a man who was so born was none the worse, nay, a great deal better, for a highly scientific education. He had pleasure in proposing a vote of thanks to the writer of the paper.

Mr. J. G. WEEKS (Newcastle-upon-Tyne), in seconding the resolution, said that as an old examiner in the Newcastle mines-inspection district he had had some experience on this subject. Prior to 1887, time spent at college was regarded as the equivalent of a certain portion of the time spent in the mine, but owing to

legislation this had been altered. It was desirable to combine the two things; they did not want any higher certificate for colliery-managers for the working of mines than the certificate of competency that they already had; and, as the President had remarked, there was a very great deal besides scientific knowledge required in coal-mining. The management of men was a most important feature; and on this subject he endorsed the President's remarks.

The motion was cordially approved, and Prof. Wertheimer briefly acknowledged the vote.

Mr. J. J. Muir's paper on the "Treatment of Low-grade Copper-ores in Australia" was read as follows:—

# TREATMENT OF LOW-GRADE COPPER-ORES IN AUSTRALIA.

By J. J. MUIR.

*Introduction.*—The latent resources of Australia as regards its future production of copper, suggested to the writer that a paper on the subject might prove of interest to members. He proposed to touch on the economic aspect of the question, before putting forward any method of profitably treating and extracting the metal from these low-grade ores. It is to the large number of isolated fire-concentration or reduction-works, spread over all parts of Australia, each endeavouring to solve the problem of the cheap production of copper on their own account, that we are indebted for the backwardness of the industry.

In the various States of the Commonwealth, large quantities of copper-ores of low grade are known to exist in the form of sulphide, which under the present conditions of working afford absolutely no hope of giving a remunerative return for the investment of capital. The rich surface-deposits overlying the sulphide-zones, and comprising the carbonate and oxides of the metal, are in a broad sense the ores that have been accountable for the copper-production of the past. Notable exceptions could be mentioned in various States, but as regards a serious attempt to deal economically with the enormous reserves of low-grade sulphide-ores, the copper-industry may be considered to be in its early infancy.

If a solution of this problem could be arrived at, the position of Australia as a copper-producing country would stand in a different position on the list at the present time.

In Mr. M. Eissler's paper on copper-production,* it is interesting to note, in a list of the principal copper-mines of the world, with their average copper-percentages, that the ore-grades of the Australian deposits compare favourably with any. It may be

* *Trans. Inst. M. E*, 1901, vol. xxi., page 315.

that the economic conditions prevailing at these foreign mines are largely more favourable than those in Australia for the cheap production of copper, but it will come little short of a revelation to Australian mining men to learn from Mr. Eissler's paper, that a profit had been made on an ore containing 0·5 per cent. of copper, and that producers in Michigan are treating, at a profit, ores containing only 0·65 per cent. of copper.

The general conditions in Australia are, that the copper-sulphide deposits of from 2·5 per cent. up to 5 per cent. are situated at remote distances from the necessary fuels and fluxes; and that the very small proportion of copper-sulphide forming impregnations in siliceous rocks, presents insuperable difficulties in regarding these ores as a fire-concentration or smelting proposition. But it is usually as such that these ores are considered, and numerous attempts are made to overcome the high cost of transport of fluxes, fuels and bases, and to complete the operations of reduction and conversion to the metal on each separate property.

It is needless to point out that under such conditions the attempt to treat successfully low-grade sulphide-ores is being made under the most adverse circumstances possible.

*Treatment.*—The question then arises as to the way in which these deposits can be properly treated, by selection from the many methods, or combination of methods that modern metallurgical skill has devised.

Leaving Tasmania out of the question, as having facilities peculiar to its own copper-fields, the writer would maintain as a broad and primary principle:—(1) That the metallurgical works for smelting and converting the ores should be centralized on the sea-board, and in proximity to cheap fuels and fluxes; (2) that at the mines, the ores should be concentrated by water to a bulk sufficiently reduced to admit of profitable transport to the smelters; and carrying copper-contents sufficient to cover the cost of producing the concentrates: thus the mine would be kept going, pending the final treatment of the tailings; and (3) that the tailings should be treated by lixiviation. As will be shown further on, the greater part of the copper-contents of the ore goes into the tailings, and it is in the last treatment that the profitable extraction of the metal must be looked for.

Metallurgical works now exist, and on a most extensive scale,

at Cockle Creek and at Dapto in New South Wales. To these works small companies and mine-owners send the ores of all metals which have been hand-picked at the mines, from every part of the Commonwealth.

It is abundantly evident that large reduction-works of this description conducted by metallurgical engineers of the highest efficiency, and provided with the most modern methods and appliances, together with cheap fuels and fluxes, can treat ores more profitably than is possible at each separate mine.

*Copper-ores.*—The ores, generally speaking, are contained in schists and quartzites or other siliceous rocks. The copper-ore that impregnates these matrices is chalcopyrite, associated with iron-pyrites, and much more rarely bornite or covelline. From the writer's analysis, detailed further on, it will be seen that a siliceous ore of this description, and of a low grade in copper, being also remote from fuels and fluxes, presents every possible difficulty in the way of profitable extraction by smelting *in situ*.

*Concentration.*—In treating these ores by the method suggested, the one and only difficulty to be overcome is the regular supply of the necessary quantity of water. In most parts of Australia, the rainfall is small and the running streams are dry in summer; but by a system of the conservation of water in excavated storage-tanks or dams, and thanks to artesian wells, the question presents no especial difficulty that has not been overcome in most parts of Australia both for mining and pastoral purposes. There is also a supplemental supply to be obtained from the mines, if shafts are sunk sufficiently deep.

In order to place before the members the fullest particulars regarding these ores, and to demonstrate the degree of concentration necessary both in bulk by weight, and increase in copper-contents, so as to produce a product that will about cover cost of production, the writer has carried out a series of practical tests and investigations on typical low-grade ores; and he subsequently analysed and weighed the resulting material, and recorded the information in tabulated form.

The first necessary factor being an accurate knowledge of the specific gravities of the copper-ores involved, and of the containing rocks, the writer made a large number of determinations of

the schists and quartzite, and found that the mean specific gravity of these rocks was 2·7. Similar determinations of the chalcopyrite-ore and the iron pyrites associated with it, both taken together, gave a specific gravity of 4·3. The bornite-ore, although very rarely found in low-grade ores, had a specific gravity of 4·9. It will be seen, from these results, that the margin of gravity-difference between the ores and the rocks, namely, 1·6, is too small to admit of a high percentage of recovery in the first product.

The writer's tests, moreover, prove that owing to the friable nature of the chalcopyrite, a large proportion is converted into slimes by the preliminary process of crushing and grinding the ore. These slimes, together with a further proportion of the ore, pass into the tailings, leaving only a small proportion of the copper-contents of the crude ore in the first product.

The writer's aim in these tests has been to obtain a degree of concentration, both in bulk by weight of material, and increase in the copper-contents of the first product, that would about cover the cost of production; and also to arrive at this result by one operation, with no return of the material for re-treatment, such as would enhance the costs.

*Experimental Concentration.*—The test which most closely gives the result will now be described.

The ore-sample used was 100 pounds of a typical low-grade ore, as previously described. It was carefully weighed on a good balance after crushing and grinding on a cast-iron board, and passed through a sieve of 40 holes to the linear inch. The ore-sample was then carefully concentrated by water in small lots, in a dish with a double riffle and by an expert manipulator.

The three products investigated in rotation will be as follows: (1) The crude ore; (2) the concentrates or first product; and (3) the tailings.

The following is the writer's percentage analysis of the crude ore, there being no gold- or silver-contents:—

| Copper. | Iron. | Silica. | Alumina. | Sulphur and alkalis undetermined. | Total. |
|---|---|---|---|---|---|
| 3·94 | 9·55 | 50·15 | 16·85 | 19·51 | 100·00 |

The concentrates, after being dried at about 100° Cent. (212° Fahr.) were found to contain by weight 7·277 per cent. of the original ore-sample tested of 100 pounds; and a separation into the tailings of 92·723 per cent. In the drying of the tailings and concentrates, roasting was carefully avoided.

The writer's analysis of the concentrates is as follows, there being no gold- or silver-contents:—

| Copper. | Iron. | Silica. | Alumina. | Sulphur and alkalis undetermined. | Total. |
|---|---|---|---|---|---|
| 11·12 | 28·40 | 14·40 | 4·60 | 41·48 | 100·00 |

The tailings, after being dried at about 100° Cent., avoiding roasting, were then assayed for copper and found to contain 3·37 per cent. As the tailings contain by weight 92·723 per cent. of the original ore-sample, this calculates out to a separation into the tailings of 3·13 per cent. of the copper-contents of the crude ore, and a recovery in the first product of 0·81 per cent. of the copper-contents of the crude ore.

The concentrates should then contain by calculation (0·81 ÷ 7·277 × 100 = ) 11·13 per cent. of copper; proving the assays to be concordant to 0·01 per cent. The small percentage of recovery of the copper-contents in the first product is accounted for by the sliming of the ore; and also to the crude ore receiving only one concentrating operation in order to avoid unnecessary costs in arriving at the desired result.

*Cost of Concentration.*—Table I. contains a statement of the cost of producing the concentrates, which takes into consideration the average Australian rates of wages, and prices of material. The writer has adopted the price of copper at £60 per ton for refined for the final product; but the profit on the process would bear a further reduction in the price. This table shows a loss of

TABLE I.—COST OF CONCENTRATING 100 TONS OF CRUDE-ORE.

| Receipts. | £ | s. | d. | Expenditure. | £ | s | d. |
|---|---|---|---|---|---|---|---|
| 7·27 tons of concentrates assaying 11·12 per cent. of copper or 0·81 ton at £60 per ton | 48 | 12 | 0 | Transport of 7·27 tons of concentrates to smelters at £1 per ton ... ... | 7 | 5 | 0 |
| Loss ... ... ... | 4 | 11 | 0 | Smelting 7·27 tons at £1 10s. per ton ... | 10 | 18 | 0 |
| | | | | Mining and concentrating 100 tons of crude ore at 7s. per ton ... ... | 35 | 0 | 0 |
| | £53 | 3 | 0 | | £53 | 3 | 0 |

nearly 11d. per ton of crude ore in producing the concentrates, but it is sufficiently close to illustrate the aim of the method as previously described, namely, to obtain the working expenses from

the concentrates. If, however, it were found in practice that the costs were higher than estimated, only closer concentration would be necessary to meet the deficiency.

*Lixiviation of the Tailings.*—In the second or lixiviation-process, the profitable extraction of the metal must be ensured, and a careful investigation should be made of the conditions of any ore which it is proposed to treat.

The result of the writer's tests clearly shows that, in the case of low-grade chalcopyrite-ores, the grinding of the material to the necessary degree of fineness to prepare it for lixiviation, pulverizes the chalcopyrite contained in the rock to so minutely divided a powder that each microscopic particle has a gravity unequal to settling in the bulk of water in contact with it, and consequently it floats away on the surface of the water. The wet concentration of these ores, therefore, can only be regarded as a preliminary process to lixiviation.

It is further evident that if the material is not ground fine enough, that the result of lixiviation will be neutralized and unprofitable, as the solvent power of the acid solution in the ore would be minimized.

In the following investigation, the writer subjected the whole of the tailings from the test to the process.

A 5 per cent. solution of sulphuric acid was adopted, on the basis of 1 ton of solution to 1 ton of tailings; and as temperature plays an important part in the time of extraction, the writer kept the vat at a mean temperature of 70° Fahr. to agree with the conditions of the climate of the central and northern States of Australia.

*Precipitation of the Copper.*—In the precipitation of the copper from the acid solution on to either scrap or pig-iron, although the theoretical proportion would be as 63 is to 56, it will be found in practice sufficiently close to allow 1 ton of iron to each ton of metallic copper-precipitates. Although the writer could not detect in the tests any re-dissolving of the copper by the 5 per cent. solution of sulphuric acid, it would be desirable for economic purposes to make frequent assays towards the end of the precipitation of the liquor.

The precipitating-troughs should be designed so that the

scrap-iron rests on false perforated bottoms. The evolution of hydrogen carries a large quantity of minute particles of copper upwards into suspension, and means should be provided so as to allow them to settle on their return to the bottom.

Table II. shows the results of the process of the extraction of the copper from the tailings. The tailings-loss is therefore 0·5

TABLE II.—SHOWING THE RATE OF COPPER-EXTRACTION BY A 5 PER CENT. SOLUTION OF SULPHURIC ACID FROM THE TAILINGS, AT A TEMPERATURE OF 70° FAHR.

| No. of Assay. | Tailings. | Copper contents. Per cent. | Copper-extraction. Per cent. |
|---|---|---|---|
| 1 | At the start | 3·37 | Nil. |
| 2 | After 11 weeks | 0·50 | 2·87 |

per cent. on 92·75 tons or 0·46 per cent. on the original 100 tons of crude ore. The time of extraction was 11 weeks; but under proper conditions the whole of the metal will be precipitated from the solution in 12 hours. The draining and drying of the final product can then be completed.

The assay of the final product gave 78·4 per cent. of copper, containing 2·65 tons of copper.

*Cost of Lixiviation.*—Table III. contains an estimate of the costs and profits of the lixiviation-process, under Australian conditions.

TABLE III.—SHEWING THE TOTAL PROFIT AND COSTS OF EXTRACTING THE COPPER FROM 100 TONS OF CRUDE ORE, ASSAYING 3·94 PER CENT.

| Receipts. | £ | s. | d. | Expenditure. | £ | s. | d. |
|---|---|---|---|---|---|---|---|
| 2·65 tons copper at £60 per ton ... | 159 | 0 | 0 | Loss on concentrates, see Table I. ... | 4 | 11 | 0 |
| | | | | 2·65 tons of pig-iron at £4 per ton ... | 10 | 12 | 0 |
| | | | | 4·63 tons of sulphuric acid at £6 10s. per ton ... ... | 30 | 1 | 9 |
| | | | | Labour, liberal allowance ... ... | 20 | 0 | 0 |
| | | | | Transport and refining charges on final product ... ... | 15 | 0 | 0 |
| | | | | Contingencies, say ... | 5 | 0 | 0 |
| | | | | Total profit on extraction ... ... | 73 | 15 | 3 |
| | £159 | 0 | 0 | | £159 | 0 | 0 |

*Conclusions.*—The copper-recovery on 100 tons of crude ore assaying 3·94 per cent. was as follows:—

| | Copper. |
|---|---|
| Recovery :— | |
| Tailings, 92·73 tons contain 2·87 per cent or .. ... | 2·65 tons. |
| Concentrates, 7·27 tons contain 11·12 per cent. or ... | 0·81 ,, |
| | 3·46 ,, |
| Loss :— | |
| Tailings, 92·73 tons contain 0·5 per cent. or ... ... | 0·48 ,, |
| Original crude ore, 100 tons contain 3·94 per cent. or ... | 3·94 ,, |

The cost of producing 1 ton of copper is £32 3s. 4d., the profit on each ton of copper is £27 16s. 8d., and the profit on each ton of the original crude ore is 14s. 9d.

In concluding this paper, a few additional remarks may be added regarding the practical application of the process. Any ore that it is proposed to treat, should be investigated as previously described, and a determination should be made of the natural acidity of the ore to be operated upon. This assay should be conducted under varying conditions of time of exposure to the air. In the case of heavy sulphide-ores in a warm climate, the utilization of the natural acid contained potentially in the ore itself would reduce greatly the cost of extraction.

In this paper, the writer has dealt with an ore containing little natural acid, but amenable to a profitable treatment by a hydrometallurgical process.

The conditions of climate require especial consideration, as it would be questionable, if the temperature of the leaching-troughs had to be raised, whether this would not materially reduce the profits. In the preliminary process of concentration, the class of ore dealt with by the writer (as previously mentioned) presented the least favourable conditions for retaining the greater proportion of copper-contents in the concentrates. But as an ore starting from the basis became higher in sulphides of copper and iron, it would proportionately increase the recovery in the concentrates, and relegate the tailings to a position of secondary importance in the process as regards copper-recovery.

What is required is a quick and cheap method of concentration to achieve the desired standard. The writer is perfecting a design of an appliance, especially adapted for the process, and he hopes at some future time to place the details and working drawings before the members in another paper.

Mr. M. Eissler (Paris) wrote that Mr. Muir's paper presented some interesting features and confirmed some of his own experience in concentrating copper-ores. Concentration of copper-ores meant failure in nine cases out of ten, and if the same had succeeded in the Lake Superior regions, it was owing to the fact that the copper was present in the ore in its metallic state and consequently separated easily from the gangue after crushing. At the Anaconda mine, in Montana, concentration preceded smelting and although this preliminary operation involved a loss of nearly 35 per cent. of the metallic contents of the ores, their abundance and the fact that the mineral was in coarse particles, which after coarse crushing permitted of a recovery of 65 per cent. of the values in the washed material, made concentration a success. In most cases, the copper-ores were finely disseminated in the gangue and then it was not sufficient to have a difference of specific gravity between gangue-rock and mineral, to effect concentration. The hardness of the matrix and the softness of the ore-particles played a most important part in this operation, as during crushing the sulphides were slimed and passed away, and the concentrates obtained assayed only a fraction higher than the original ore, while in some cases the tailings were proportionately richer than the original ore.

He thought that Mr. Muir had nearly stumbled across such an ore, as it originally assayed 3·94 per cent. of copper and after concentration the tailings still contained 3·37 per cent. Therefore, there was only a recovery of 0·57 per cent. of copper in the concentrates, and under such conditions he (Mr. Eissler) could not see any reason why concentration should be adopted. He did not wish to criticize the cost of concentration established by Mr. Muir in Table I., especially as he did not know to which locality he referred, but it was rather doubtful to his mind, and he said this from personal experience, that mining and concentrating charges could be covered by 7s. a ton in any of the Australasian colonies.

Sulphuric acid was the agent which played a great rôle in dissolving copper in the hydro-metallurgical treatment of copper-ores, and if they lent themselves to the natural production of sulphates by exposure to atmospheric agencies, the whole question became very much simplified, as had been the case at the Rio Tinto mines. The natural decomposition of the sulphides into cuprous and ferrous sulphates could be assisted by saturating them

with a brine containing ferrous sulphate. He believed that if the richer sulphide-ores were picked out at some mines and utilized for the manufacture of sulphuric acid on the spot, the foundation would be laid for the treatment of the low-grade ores, as the acid must be cheap to permit of its employment. Of course, in any process where Nature did the work, a long period of time elapsed before a complete chemical change took place, and enormous ore-heaps must undergo simultaneous treatment to make it profitable, necessitating a large lock-up of capital. At the Rio Tinto mines, enormous profits were made by such methods out of 2½ per cent. ores, and copper was produced there at less than £25 a ton, whereas it cost £40 a ton to make copper at most of the American mines. He thought that Mr. Muir would be much safer in figuring on a consumption of 2 tons of iron per ton of copper produced during precipitation, as there was a wide margin between theoretical figures and practical results in this department.

The problem that Mr. Muir proposed to solve was not an easy one, but he believed that he was working in the right direction. Every individual case, however, would require close investigation on a practical working scale; and the problem of hydro-metallurgical treatment of low-grade copper-deposits in the Australian colonies would, in his opinion, depend on the price at which sulphuric acid could be obtained on the spot.

The PRESIDENT (Mr. J. S. Dixon) proposed a vote of thanks to Mr. Muir for his paper, which would form a valuable addition to the *Transactions*.

Prof. H. LOUIS seconded the resolution, which was cordially approved.

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Mr. A. R. SAWYER's paper on "The Tarkwa Gold-field, West Africa" was read as follows:—

# THE TARKWA* GOLD-FIELD, WEST AFRICA.

By A. R. SAWYER.

This note is merely an amplification of the paper read last year; and the writer hopes that the geological sketch-maps (Figs. 1 and 4, Plates XXIV. and XXV.) and sections (Figs. 2 and 3, Plate XXIV.) now appended, will facilitate a proper understanding of his previous remarks.

FIG. 5.—DWELLING-HOUSE ON THE TOP OF AJOPANG RIDGE.

He now definitely puts forward the following table of the formations occurring in this gold-field, in stratigraphical order:—

*B. Clay-slate Formation*—
Sandstone, fine-grained, green and white, not thick.
Clay-slate, over 1,000 feet thick.
Sandstone, fine-grained, green and white, very thin.

*A. Banket Formation*—
Consisting principally of sandstone, more or less coarse; quartzite; conglomerate, more or less auriferous; slate, not more than a few inches thick; and some calcareous beds.

* This being now the recognized spelling, the writer proposes to substitute it for "Tarquah," used in his previous paper, 1901, vol. xxii., page 402.

The writer is confirmed, by a second visit to the Gold Coast, in his opinion that the clay-slate formation conformably overlies the banket formation, and that some fine-grained greenish-white sandstone intervenes between the clay-slates and the banket formation. This assumption is merely based on the occurrence of a huge boulder lying in that position, which could not have been derived from the sandstone-beds, similar in character, which undoubtedly overlie the clay-slate. The clay-slate formation contains white quartz-veins, some of which are thick.

FIG. 6.—INTERIOR OF THE WRITER'S HOUSE ON THE TOP OF AJOPANG RIDGE.

Further exploration, in the neighbourhood of Kotra-Verchey, has convinced the writer that his surmise is correct, that other synclines besides the main Tarkwa syncline might occur. He has determined the occurrence of two anticlines with their attendant synclines, with a trend parallel to the Tarkwa ridge (which probably is also part of an anticline) between Tarkwa and Kotra-Verchey. These anticlines are shown in Fig. 2 (Plate XXIV.).

The writer had some tunnels or adits driven into the side of the Ajopang range, which is 650 feet above sea-level and synchronizes with the north-western anticline, and he was fortunate enough to discover two conglomerate-reefs as shown in the section (Fig. 3, Plate XXIV.). The thickness of the thinnest reef varies between 4 and 5 feet, and it contains small pebbles; and the thicker reef, including a few sandstone-bands, is about 19 feet,

and it contains larger pebbles, up to 4 inches in length. Detailed sections of these reefs are shewn in Tables I. and II.

FIG. 7.—TUNNEL ON AJOPANG RIDGE: THE WRITER AND ANOTHER EXAMINING A BANKET-FIND.

TABLE I.

| | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|
| *Hanging-wall* :— | | | | |
| Sandstone, striped, with numerous hæmatite-venules; distinct bedding-planes ... ... | — | | | |
| Conglomerate ... ... ... ... ... ... | 0 | 8 | | |
| Sandstone, striped ... ... ... ... ... | 0 | 10 | | |
| | | | 1 | 6 |
| *Reef* :— | | | | |
| Conglomerate, light-coloured, with iron venules* ... | 1 | 10 | | |
| Conglomerate: red band, 3 inches ... ... (Ft. 0, In. 3) | | | | |
| light ,, ... ... ... † | | | | |
| red band, 3 inches ... ... 0 3 | | | | |
| light ,, ... ... ... † | | | | |
| | 1 | 3 | | |
| Conglomerate, dark, much hæmatite ... ... | 1 | 1 | | |
| | | | 4 | 2 |
| *Foot-wall* :— | | | | |
| Clay ... ... ... ... ... ... ... | 0 | 1 | | |
| Sandstone, striped ... ... ... ... ... | 1 | 10 | | |
| Sandstone, with some quartzite ... ... ... | 0 | 11 | | |
| Grit, with small pebbles about the size of a pea, and much talc and chlorite ... ... ... ... | 1 | 9 | | |
| Grit, the same as above, with several amethyst-coloured pebbles ... ... ... ... ... | 1 | 7 | | |
| | | | 6 | 2 |

* The pebbles are mostly up to 1 inch long, some near the top of the reef reach 2 inches in length and they are well-rounded and mostly composed of translucent quartz and amethyst.

† These thicknesses cannot be supplied, owing to the author being abroad.—EDITOR.

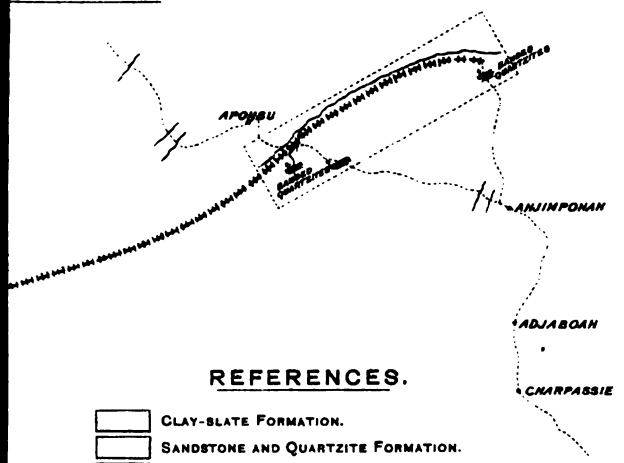
TABLE II.

| | Ft. | Ins. | Ft. | Ins. |
|---|---|---|---|---|
| *Hanging-wall* :— | | | | |
| *Reef* :— | | | | |
| Red clay ... ... ... ... ... ... ... | 0 | 5 | | |
| Sandstone, striped, with a few pebbles ... ... | 2 | 1 | | |
| Sandstone, with pebbles ... ... ... ... | 0 | 8 | | |
| Conglomerate, with pebbles up to 2 inches long ... | 1 | 1 | | |
| Sandstone, with large pebbles... ... ... ... | 0 | 3 | | |
| Conglomerate, with pebbles up to 3 inches long ... | 2 | 9 | | |
| Sandstone ... ... ... ... ... ... ... | 0 | 8 | | |
| Conglomerate, with pebbles up to 3 inches long ... | 1 | 8 | | |
| Red sandstone ... ... ... ... ... ... | 0 | 2 | | |
| Conglomerate ... ... ... ... .. ... | 1 | 6 | | |
| Sandstone ... ... ... ... ... ... ... | 1 | 3 | | |
| Conglomerate .. ... ... ... ... ... | 0 | 7 | | |
| Conglomerate, dark purple, with pebbles up to 2½ inches long ... ... ... ... ... ... | 2 | 6 | | |
| Conglomerate, oily, purple, with well-rounded pebbles ... ... .. ... ... ... | 1 | 8 | | |
| Conglomerate, with pebbles up to 2 inches long, but not many ... ... ... ... ... | 2 | 1 | | |
| | | | 19 | 4 |
| *Foot-wall* :— | | | | |
| Sandstone ... ... ... ... ... ... ... | 5 | 4 | | |
| Grit... ... ... ... ... ... ... ... | — | | | |
| | | | 5 | 4 |

FIG. 8.—SINKING A SMALL SHAFT ON AJOPANG RIDGE.

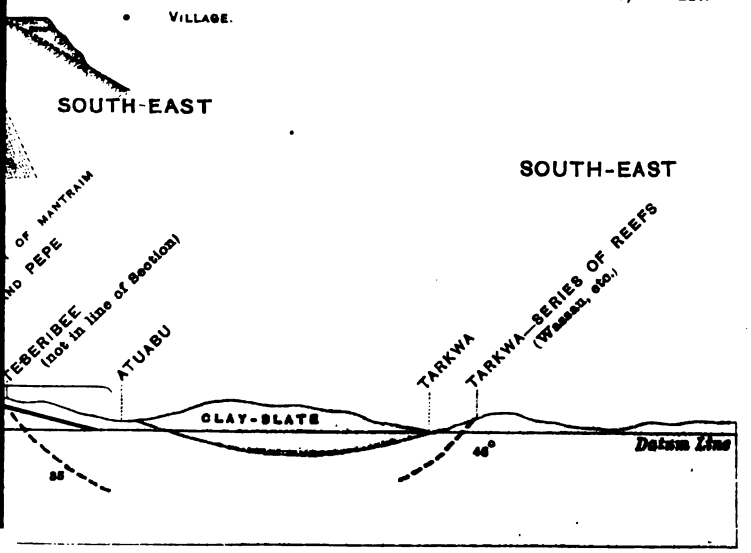
With regard to certain parts of this gold-field, the writer i strongly of opinion, as stated previously, that the banket forma tion has been disturbed from its original position by a tangentia thrust which has had the effect of bending it into folds; and, that in places, the strata have broken instead of bending, and reverse

*Gold-field."*



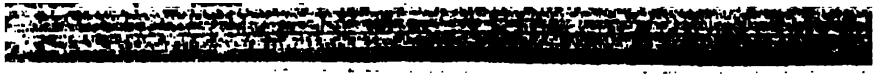

## REFERENCES.

- Clay-slate Formation.
- Sandstone and Quartzite Formation.
- Basic Igneous Rocks: Dolerite, Diabase.
- Probable Dykes.
- Intermediate Igneous Rocks: Diorite, Andesite.
- Probable Clay-slate Formation.
- Probable Sandstone and Quartz Formation.
- Conglomerate Reefs shewing the Strike.
- Quartz Reefs and Veins and Boulders.
- Dip of Reef or Formation.
- Direction of Flow of River or Stream.
- Rivers approximately correct.
- Rivers very uncertain.
- Strike of Formation.
- Sekondi-Tarkwa Railway with Mileage from Sekondi.
- Approximate Line of Railway from Tarkwa to Aponsu (being continued to Koomasi)
- Paths.
- Streams.
- 260' Elevation above Sea-level, in Feet.
- Bore-hole.
- Shaft.
- Tunnel.
- Boundaries of some of the Concessions, 6,000 feet by 6,000 feet.
- Village.

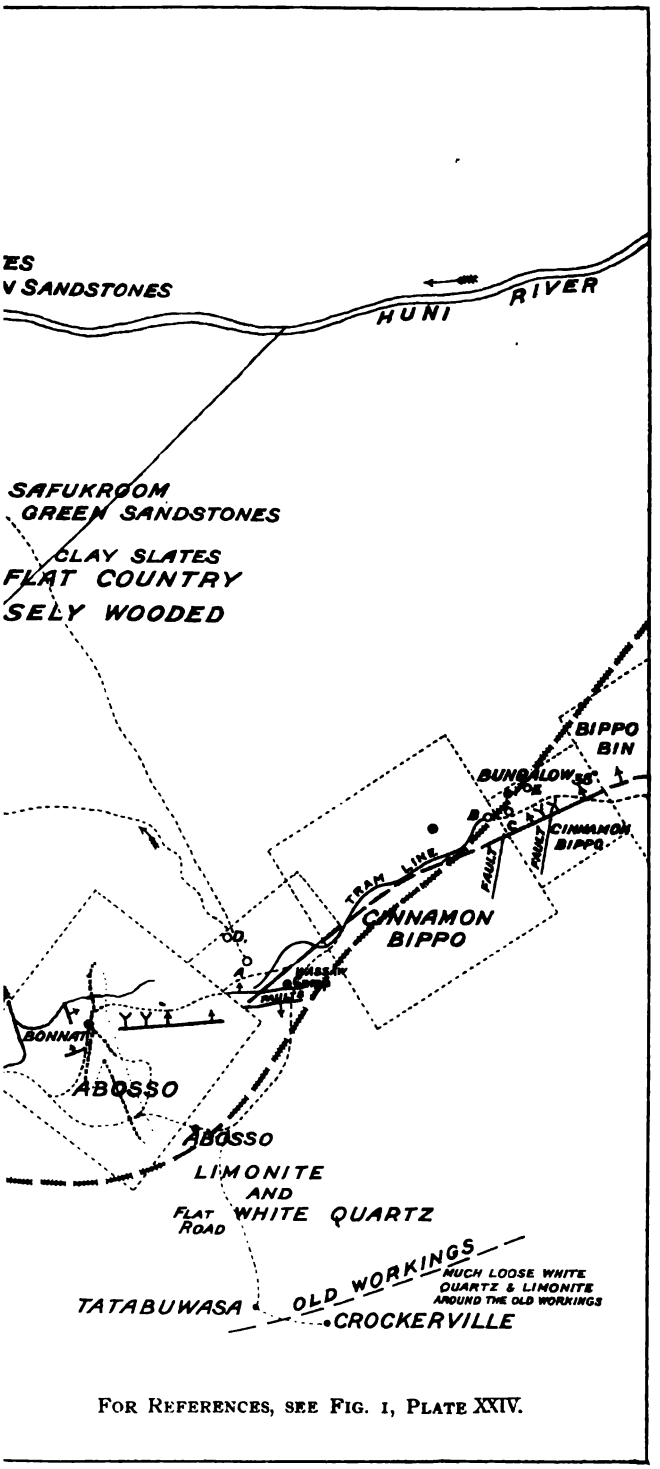



IELD.

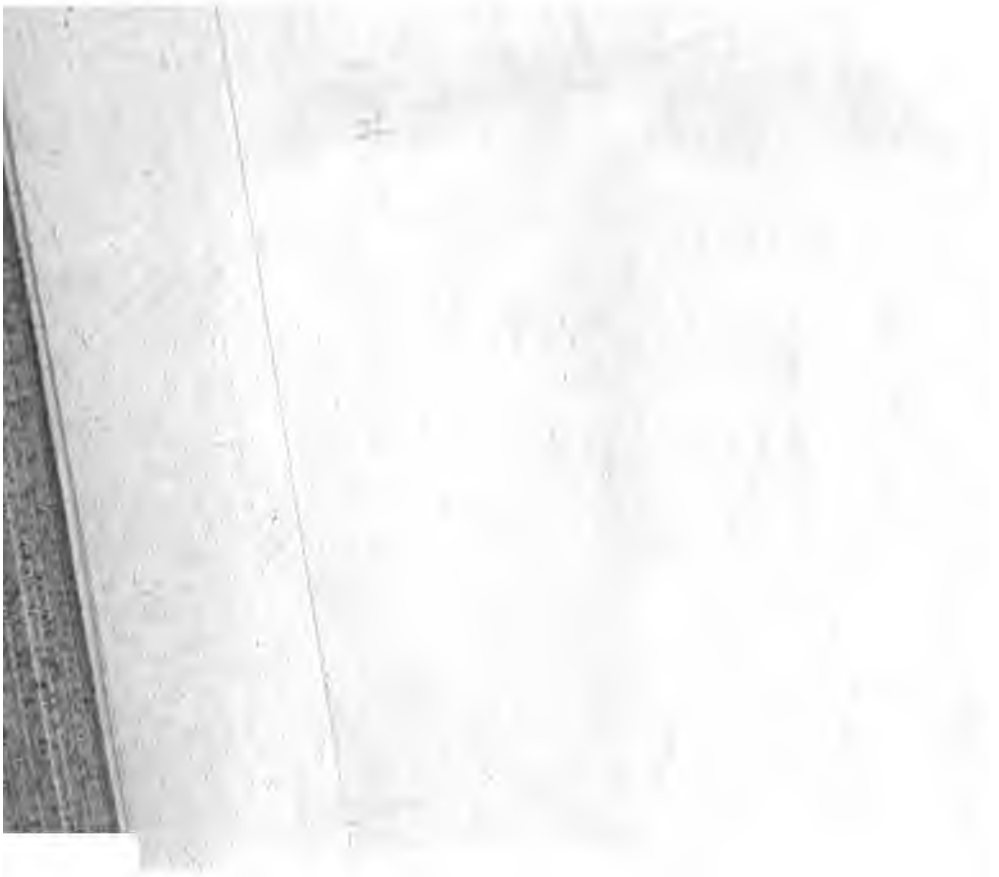
Scale, about 1 Mile to 1 inch.



FIELD.




For References, see Fig. 1, Plate XXIV.



faults have thus been created. In this respect it resembles the Rand, where most of the larger faults are reversed faults, the reefs being, in some instances, thrown up considerably.

Prof. HENRY LOUIS (Newcastle-upon-Tyne) said that his recollection of the West African gold-field went back about 20 years, and he was glad to see the point that he wanted to bring forward had been referred to by Mr. Sawyer, namely, the difference between the West African banket and the South African. Most writers had tried to make out that they were identical, but the micro-structure was quite different. In South Africa, the pebbles were cemented together, chiefly by some secondary quartz with chlorite and other minerals, and there was a great deal of pyrites, which was practically absent in the other case, where the cementing material consisted of quartz shewing at times threads of rutile, and a little ilmenite. In South Africa, the colour was a dark red, while in West Africa it was white, of course both occurrences were so far similar that both were banket-beds, as he had long ago pointed out, but the differences should not be slurred over because there were great points of similarity.

Mr. A. R. SAWYER said that in many ways the similarity was very striking; if a piece of core from the quartzite of the West Coast was compared with a piece from the Rand in depth it was difficult to distinguish between them; they were both of a pale greenish colour, and taking everything into account, there was much more similarity than dissimilarity in the two formations. The conglomerates of the two formations are as nearly alike as two series of banket-beds can possibly be. In both series, the pebbles consisted principally of white quartz; and black pebbles occur in both. He saw little dissimilarity in the matrices of both series; and the only difference, as he pointed out, was that the oxidized portions of the banket-beds continue to a greater depth at Tarkwa than on the Rand.

The PRESIDENT moved a vote of thanks to Mr. Sawyer for his paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

Mr. F. W. PAYNE's paper on "Gold-dredging in Otago, New Zealand," was read as follows:—

# GOLD-DREDGING IN OTAGO, NEW ZEALAND.

By F. W. PAYNE.

Gold-dredging in New Zealand has conformed to the natural laws of evolution in a striking manner, in that there have been no sudden changes from the crude methods of the early diggers to the present-day dredges equipped with all their machinery and appliances.

The early diggers worked on the river-banks, and after removing top stuff and stones, etc., put the wash-dirt through their

Fig. 9.—Bendigo Company's Gold-dredge on the Clutha River.

cradles and saved the gold on plush or other catchment. The cradle consisted of a box, about 4 feet long by 2 feet wide and 2 feet deep, with a perforated tray, the screenings from which fell on to a plush-mat. The water was supplied by a ladle kept going by one hand of the operator, while with the other hand he rocked the machine, which was on rockers or suspended from two points. The water flowed over the plush-mat and the rocking action caused the small stones and light sand to be washed off, leaving only the gold on the mat. It may be here remarked that, up to the present time, no better method has been found for the saving of fine gold, apart from amalgamation.

*Spoon-dredge.*—The diggers made their harvest while the rivers were at a low level, during the winter months, and were naturally led to desire to get still further into the river-bed: so the spoon-dredge was the outcome of their desire. The spoon-dredge consisted simply of a wooden pontoon, moored in the river with ropes operated by a hand-winch. The spoon itself was merely a bag, generally of green-hide, and fitted with a steel lip or mouth. It was attached to the end of a wooden arm or lever, was swung down into the river and into the wash, and drawn up again by a winch. The stuff was then washed in the cradles as before.

FIG. 10.—PONTOONS OF THE KAWARAU BRIDGE GOLD-DREDGE.

*Bucket-dredge.*—From the spoon-dredge to the bucket-dredge, fitted with automatic gold-saving appliances, was perhaps the greatest advance made at one step in the history of what has come to be known as "the dredging-industry." In 1882, the Dunedin Gold Steam-dredging Company, Limited, was formed, and the work of designing and building a dredge with a continuous chain of buckets, equipped with steam-winches for moving about the river, and furnished with automatic gold-saving appliances, was entrusted to the then well-known firm of Messrs. Kincaid and McQueen, engineers, of Dunedin. Mr. McQueen has been called the father of gold-dredging, and probably if this term can be applied with justice to any man, he deserves that name. The

Dunedin dredge, though by no means a perfect machine, and requiring many alterations in its main design and proportions, ultimately emerged from the maker's hands as a workable machine; it has only ceased to work within the last 12 months, and was then sold for removal to another claim. The dredge as originally constructed was equipped with two ladders, hung one on each side of the hull, but this was found to cause too much oscillation in the water, due to first one string of buckets and then the other, getting into harder or softer material. The hull, which was built of steel plates and angles, was then cut down the middle, and a well formed for the reception of one of the ladders, and this style has been adopted ever since.

FIG. 11.—LADY RANFURLY GOLD-DREDGE ON THE KAWARAU RIVER.

In 1891, several dredges were built to an improved design, and there are some of these still at work. As the gold in some cases was found to lead into the banks or into shallow water, the material picked up by the buckets and deposited over the stern, accumulated and heaped itself up, and sliding down to its angle of repose fouled the stern of the dredge, which was thus continuously forced ahead and so could not work the ground except in patches. The obvious way out of this difficulty was to elevate the tailings. The credit of the invention, if it can be so called, of an elevator for dredge-tailings is claimed by various persons, but there can be no doubt that the idea occurred to numbers of dredging-engineers and was discussed pretty generally before it was actually applied to a dredge.

In the early nineties, Mr. L. Gards had an elevator made, which, not proving up to his expectations, was discarded, almost

without trial. In 1895, two elevators were made almost simultaneously, both getting to work about the same time proved practical successes, and were immediately adopted by other dredges.

The Clutha, the chief dredging-river in New Zealand, being in most of its course a swift stream, the river itself was in some instances used as the motive power. The method adopted being two paddle or current-wheels, one at each side (like paddle-steamers) these were connected to a cross-shaft, which in turn was geared to the top-tumbler of the string of buckets. The water for washing the material lifted, was supplied by small buckets attached to the arms of the current-wheels, these emptied the water which they brought up into a trough as they were tilted,

FIG. 12.—SANDY POINT GOLD-DREDGE.

and the water was led to the gold-saving tables. The objections to the current-wheel dredge are the impossibility of following a lead of gold into the bank or into quiet-water, and the comparatively small power available even when in the current.

With the general adoption of the tailings-elevator, the flats outside the river-bed began to be worked by the dredges, and this introduced what is now known as the dry-land dredging. This consists of dredging in a small dam or paddock, as it is generally termed, and this dam accompanies the dredge in its workings by necessity of the excavating by the buckets forward and the filling in by the elevator at the stern.

Large tracts of flat country containing auriferous wash, deposited probably by early-river courses, are now being worked by

dredges with good results. In most cases, the land used for dredging purposes in New Zealand is useless for agriculture, and thus the turning of the stones and gravel to the top, as is usually done in dredging, is of no serious consequence.

*Gold-dredge.*—Having outlined, in a general way, the stages of the dredging industry, some account of the actual machinery of a dredge as now employed may be of interest (Figs. 1 and 2, Plate XXVI.)* The gravel-wash, as already stated, is lifted by means of an endless chain of buckets operated by tumblers. The top-tumbler is the driving-tumbler, and obtains its power from the engine by belt or driving-ropes and spur-gearing. Manilla driv-

FIG. 13.—DUNSTAN LEAD COMPANY'S GOLD-DREDGE.

ing-ropes have been largely used by the writer with unvarying success, the system mostly adopted in connection with them being to use only one intermediate shaft between the engine and the top-tumbler shaft, thus simplifying the machinery considerably. From the nature of the work, the power given out varies enormously in short intervals of time and also at, say, any moment. The buckets may strike a huge boulder impossible to lift, and some system of friction-driving is essential, to avoid breakage which would otherwise be inevitable. The usual method is by a simple form of friction-clutch (wood-lined) which can be released or put into gear by the man in charge of the winch. The winch is used for moving the dredge, and for raising and lowering the ladder.

* Reproduced from *Papers and Reports relating to Minerals and Mining, New Zealand*, 1900. C.–3, page 48.

The usual method adopted in working the ground can best be understood by a reference to the accompanying rough sketch (Fig. 3, Plate XXVII.). The dredge is shown working in the direction of the arrow, and the worked ground is indicated behind. The dredge works alternately from A to D, and at each starting-point, A and D, it is pulled ahead on the head-line, H, some 2 feet, and so a fresh cut is taken all along the working-face, AD, the tailings being deposited by the elevator on a heap, E.

To return to the machinery of the dredge itself, the material, being lifted by the buckets, is delivered over the top-tumbler into a chute, which directs it into the revolving-screen, perforated with variously sized holes. The fine material, that passes through these holes, falls on to the gold-saving tables, which are supplied with

FIG. 14.—ELEVATOR OF THE DUNSTAN LEAD COMPANY'S GOLD-DREDGE.

plenty of water (from 1,500 to 2,000 gallons per minute, supplied by a centrifugal pump), and are covered with cocoanut matting, above canvas, and with wire netting or expanded metal over the matting. The wire forms an obstruction to the material; and the gold, being the heaviest, is caught in the mesh and driven into the matting by the action of the water; and in the case of fine gold, it is driven through the matting on to the canvas. In the meantime, the coarse material that passes through the end of the screen is either deposited into the river through a chute, or is delivered into the elevator-buckets.

In some cases, especially in dry-land-dredging, where much clay is encountered, the screen is removed, and the spoil is merely

run over a long spread of tables, from 3 to 6 feet wide; but in such cases the matting is usually protected by perforated plates or ripple-bars in place of the wire-netting.

So far, all attempts at mercurial-gold saving, in connection with dredging, have proved failures, due to the large amount of material to be turned over, and the presence in considerable quantities of minerals which quickly "sicken" the mercury.

In some cases, where there exists a large over-burden of clay, the saving of gold is rendered very difficult by the clay, rolling inside the screen or over the tables, collecting the gold on its surface and carrying it overboard. This difficulty has been to a

FIG. 15.—ALEXANDRA LEAD COMPANY'S GOLD-DREDGE.

great extent overcome by what is known as advance-stripping, which consists of working at two levels instead of always working on the actual bottom. The buckets are lowered to work to a depth to lift the clay and leave the gravel for the next cut. The clay not being auriferous is not treated on the tables, but is delivered to the elevator, by which it is deposited a considerable distance from the stern of the dredge; and when some extent has thus been stripped the dredge is dropped back and the gravel dredged. This is comparatively clean and easily washed (Fig. 4, Plate XXVII.).

*Tailings-elevators.*—During the past few years, considerable improvements have been made in the general design of the dredges. No doubt much greater improvements would have

been made, but for the fact that consulting engineers and others have been so fully occupied in meeting the demand for dredges; and also but for the reluctance on the part of directors to take any risk with experiments of any sort. The most radical departure from the ordinary methods of working is the invention of the centrifugal tailings elevator-wheel, which was first suggested by Mr. Walter Peck, who was engaged as a draughtsman in the writer's office. Experiments were immediately conducted by Mr. Peck and the writer, and the Payne-Peck centrifugal elevator was introduced in the early part of 1901. Naturally there was some diffidence in testing the invention, but ultimately the Ngapara Dredging Company of Alexandra, Otago, used an elevator to stack

FIG. 16.—NGAPARA NO. 3 GOLD-DREDGE.

tailings to a height of 18 or 20 feet. The machine has been in steady work for about 5 months, with satisfactory results. The saving in first cost by the use of this form of elevator is very great, especially where the tailings have to be stacked to any considerable height.

In a dredge, designed by the writer, the elevator is 145 feet long between the centres of the top and bottom tumbler (Figs. 1 and 2, Plate XXVI.), and to carry this enormous overhanging weight (some 80 tons), the pontoons were built extra wide and deep aft, and high poppet-heads were erected to carry the ties. At a low estimate, the use of the centrifugal elevator in this case would have effected a saving of £4,500 to £5,000 in the cost of the dredge. As regards repairs, there being so few wearing parts in the centri-

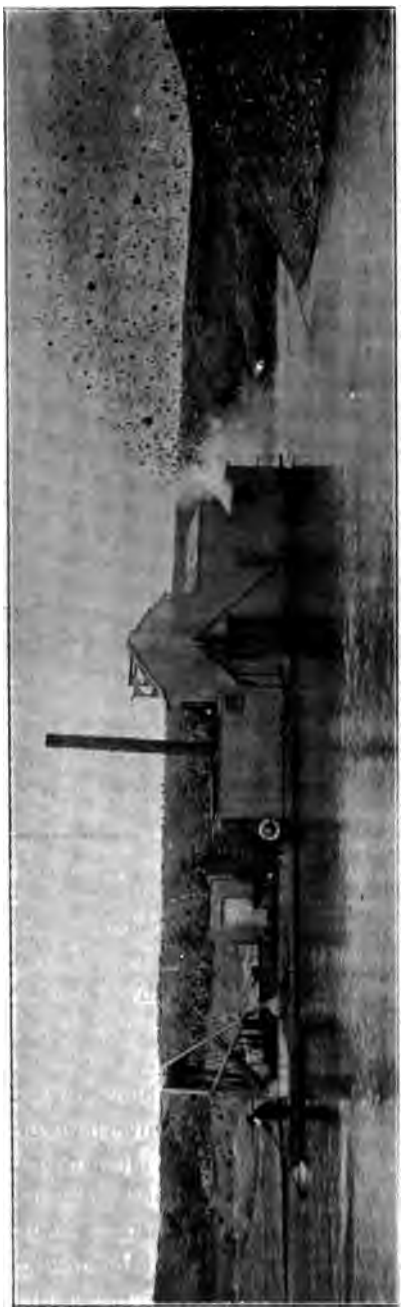


FIG. 17.—NGAPARA GOLD-DREDGE, NEAR ALEXANDRA, SHOWING THE PAYNE-PECK CENTRIFUGAL ELEVATOR AT WORK.

fugal elevator compared with the bucket-elevator, the repairs of the former are only a fraction of those required for the latter.

A tailings-elevator is at present being constructed to replace one of the largest elevators now at work, namely, the Sandy Point dredge, and it is expected that the new elevator will be at work early next month. Fig. 12 shews the dredge with the present elevator, Fig. 17 shews the Ngapara dredge, with the tailings-elevator, and Figs. 5 and 6 (Plate XXVII.) is a rough drawing of the machine.

*Gold-saving.*—No doubt, in the course of the next few years, other improvements will be introduced, and there is especially room for improvement in the gold-saving apparatus, which at the present time must strike any mining-engineer, used to the saving of gold in connection with crushing, as crude in the extreme. The difficulty that presents itself at every turn is how to treat the quantity of material lifted, in the time and space available. The average dredge lifts from 100 to 120 tons of wash per

hour, and of this, some 25 per cent. will be received on the tables. Where much black sand is mixed with the gravel, the difficulty is increased, as it is impossible to save gold on mats that have become covered with black sand, and, on the other hand, if such a supply of water is used and sufficient fall given to the tables to clear the black sand, a proportion of the gold is also washed away.

The most successful form of table that has been used by the writer is shown in Figs. 7 and 8 (Plate XXVII.):—The chief feature is a tongue or diaphragm, C, under which all the material has to pass and rise on the other side, before getting into the run of the tables, E. The tongue is intended to force the gold to settle in the box, G. The tables, E, are covered with matting, etc., in the usual way.

*Conclusion.*—As the dredging-industry in New Zealand is described by some engineers as being highly remunerative, and by others as an absolute failure, a few words on the financial aspect may not be out of place. There is no gainsaying that there have been a considerable number of failures in dredging-ventures, but the writer ventures to assert that at least 50 per cent. of the failures have been due to companies being floated with insufficient capital, and not to the want of gold in the claims that they were intended to work. Too often a dredge has been got to work only after extraordinary exertions and expensive financing, and in such a case, unless gold is found at the very outset, the company cannot continue, and so the claim is abandoned without receiving a trial. In a considerable number of cases, companies have been wound up without making a start at dredging, from what has been described as pure "funk" on the part of the shareholders. The large proportion of the dredges actually at work are payable ventures, and all indications point to a renewal of the industry on a sounder basis. A glance at the official returns will give a better idea of what working-dredges are doing, and will afford a fair idea of the actual profit. Working expenses and repairs, office-expenses, etc., may be averaged at 12 to 14 ounces of gold per week, and the capital of a dredging company averages between £7,000 and £8,000.

The photographs which accompany this paper illustrate the various matters described.

This paper by no means exhausts the subject, but the writer trusts that sufficient data have been included, to prove of interest to the members of the Institution.

## DESCRIPTION OF ILLUSTRATIONS.

FIG. 9.—The Bendigo Company's gold-dredge, designed by the author, is working about 7 miles below Alexandra, on the Clutha river. This is a typical river-dredge.

FIG. 10.—Pontoons of the Kawarau Bridge gold-dredge, ready to receive machinery. The pontoons are 105 feet long, 26 feet wide and 7 feet deep. The Kawarau Bridge, about 18 miles from Queenstown, is seen spanning the river, almost directly above the pontoons.

FIG. 11.—The Lady Ranfurly gold-dredge, designed by the author in 1898. This dredge is still the largest and most powerful river-dredge in the Cromwell district. The buckets have a capacity of 6 cubic feet, and the dredge can work to a depth of 50 feet below water-line; the centres of the ladder being 75 feet apart. A short elevator only is required, as there are no high banks. This dredge was formally started by Lord Ranfurly, hence it is named the "Lady Ranfurly." It is the property of the Electric Gold-dredging Company, Limited, and is working about 3 miles above Cromwell on the Kawarau river.

FIG. 12.—The Sandy Point gold-dredge, designed by the author in 1899, up to the commencement of work by the Dunstan Lead Company's dredge, was the largest gold-dredge in New Zealand. The buckets have a capacity of 7 cubic feet. The engine is 20 horsepower. The multitubular boiler is externally fired, and carries a pressure of 150 pounds per square inch. The dredge can work to a depth of 40 feet below water-line, and can stack tailings to 40 feet above; the elevator being 82 feet long between centres. The water in the dredging-dam is above the level of the Clutha river, which may be seen in the near distance, the level being maintained by water brought in by a race from the Fraser river. It is working about 3 miles from Alexandra. The elevator has been replaced by a Payne Peck centrifrugal elevator.

FIG. 13.—The Dunstan Lead Company's gold-dredge, designed by the author, is the largest dredge at work in New Zealand. The leading dimensions are:—Length, 112 feet; width, forward, 36 feet; width, aft, 45 feet; depth, forward, 6½ feet; depth, aft, 9½ feet; capacity of buckets, 7 cubic feet; ladder, 63 feet between centres; and elevator, 120 feet between centres. The elevator is shown working at the lowest position of the top tumbler, the full extent being marked X.

FIG. 14.—Elevator, 120 feet long between centres, of the Dunstan Lead Company's gold-dredge.

FIG. 15.—Alexandra Lead Company's gold-dredge, designed by the author, and of the same general proportions as the Dunstan Lead dredge. An elevator is not required, at present, as the dredge is working in the river. The Alexandra Bridge is shown in the photograph. The Clyde Company's No. 1 dredge is seen below the bridge.

FIG. 16.—The Ngapara No. 3 gold-dredge, designed by the author, is working off the river at Nevis, about 25 miles from Cromwell.

FIG. 17.—The Ngapara gold-dredge, near Alexandra, shewing the Payne-Peck centrifrugal elevator at work.

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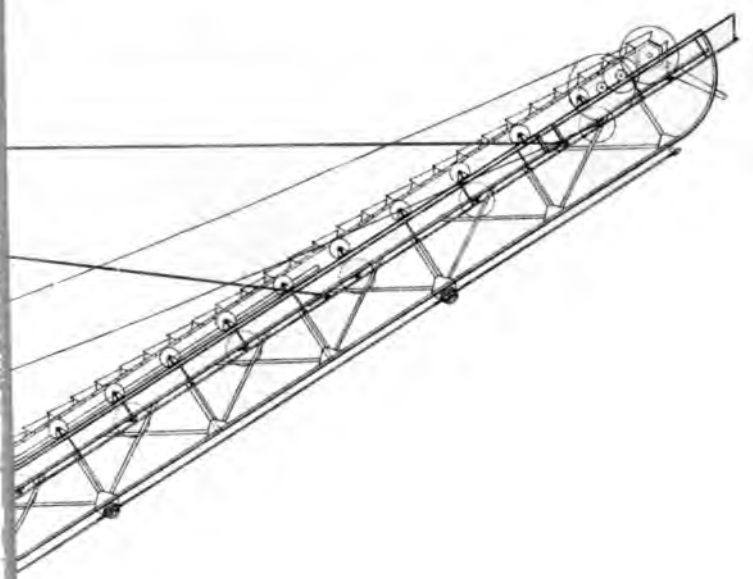
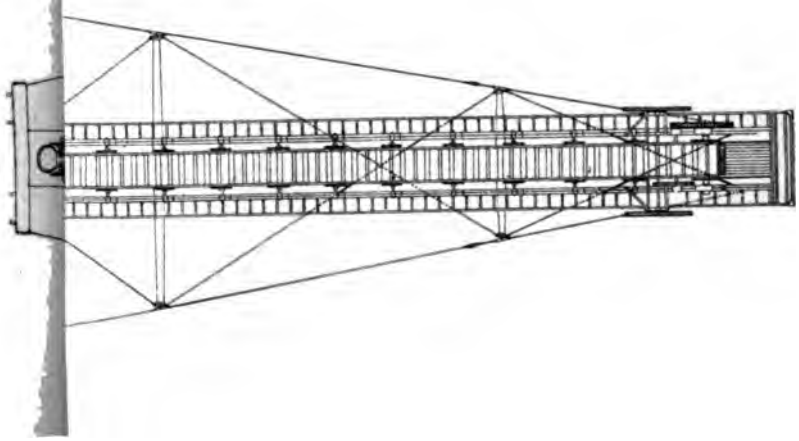
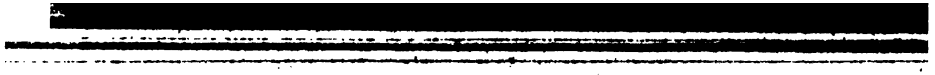
Mr. W. DENHAM VERSCHOYLE (Seattle) wrote that he had had the pleasure of knowing Mr. Payne and his work in New Zealand, and thought, from his lengthy acquaintance with dredging since its inception in that country, that he was eminently qualified



# GENERAL ARRANGEMENT OF A GOLD DREDGE.

*Scale, 20 Feet to 1 Inch.*





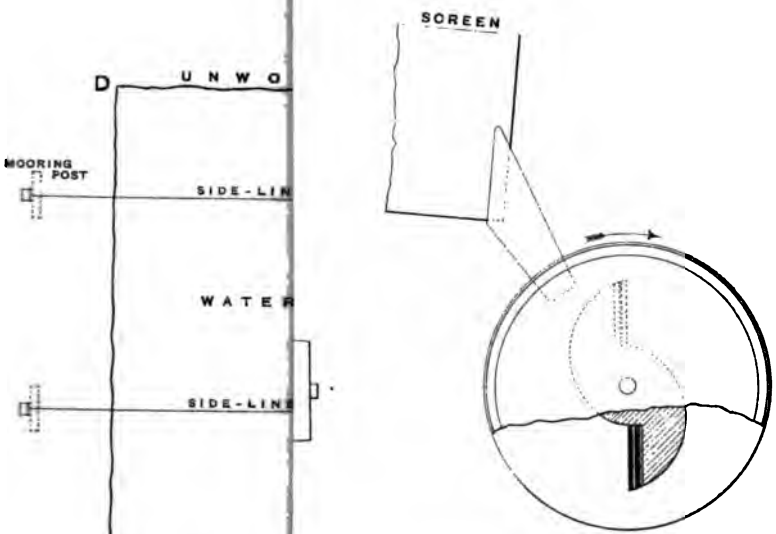
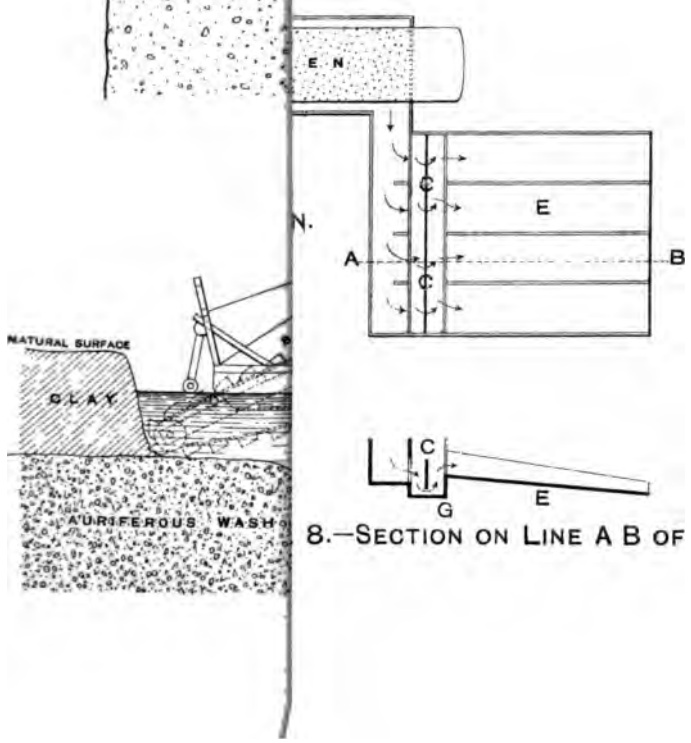
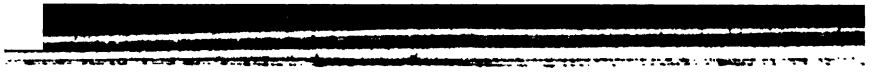



FIG. 6.

CENTRIFUGAL TAILINGS-ELEVATOR.




8.—SECTION ON LINE A B OF FIG. 7.



to write on the subject. It was to be regretted that Mr. Payne had not gone into the whole subject exhaustively. It was a large subject, a new one, and one that would admit of much writing, and it would obviously be advantageous to have all information from the most authentic sources possible. To him, the most interesting information contained in Mr. Payne's paper, concerned the Payne-Peck centrifugal elevator. This was an innovation that had been introduced since he left New Zealand, and was entirely novel to him. He (Mr. Verschoyle) tried to introduce a centrifugal elevator on a dredge that was working in a very sandy formation, where it was difficult to get an ordinary elevator to work satisfactorily, but was unsuccessful in the attempt. It would be interesting to know whether the Payne-Peck elevator would work equally well in all classes of gravel—coarse and fine. Although dredging for gold probably originated, and was brought to practical perfection, in New Zealand, he had noticed that American engineers had in some respects improved on New Zealand designs. One of the improvements that appealed to him was the pilot-house, which he had not seen on any New Zealand dredge. The winch, engine, friction-clutch, etc., were all operated by levers in the pilot-house, which occupied a prominent position, high up in the front of the dredge, over the main-bucket ladder, and gave the winch-man splendid control of the dredge and a point of vantage from which the whole operation of the dredge could be superintended to perfection. He thought that it was an innovation that might well be introduced into New Zealand practice.

The PRESIDENT moved a vote of thanks to Mr. Payne for his interesting paper.

Mr. M. WALTON BROWN seconded the resolution, which was cordially approved.

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Mr. W. R. COOPER's paper on "Electric Traction on Roads and Mineral Railways," was read as follows:—

# ELECTRIC TRACTION ON ROADS AND MINERAL RAILWAYS.

By W. R. COOPER, A.M.Inst.C.E.

## I.—*Introduction.*

Electric traction on railways has recently received a great deal of attention, chiefly from the restricted point of view of passenger traffic. But the whole question is really very much broader, for railway traffic may be divided into three classes, namely:—(1) Traffic on urban lines which provide a service for passengers exclusively, or nearly so; (2) passenger traffic on main lines; and (3) goods and mineral traffic on main lines. For urban lines, such as tube-railways, and also for suburban lines, there is no question that electrical methods are of the greatest value. The electric locomotive has the great advantage that it is able to accelerate at a much higher rate than the steam-locomotive, and at the same time is able to run at a high speed if necessary. Consequently, electrically worked trains are able to give a more rapid service and to cope with a heavier traffic than those worked by steam, and since an increase in traffic generally follows the introduction of electric traction, it pays to use electrical methods even if there is an increase in cost.

*Main-lines.*—The case of main-lines is very different, because the introduction of electrical methods would not necessarily mean a large increase in the traffic, or an increase in the capacity of the line. The success of electric traction in such cases, therefore, depends more on the reduction of the running costs in some way. Now in looking over the various classes of traffic which are carried by a main-line, it is apparent that passenger-trains are worked under fairly economical conditions, and that the running costs are low so far as the fuel is concerned. But the conditions are different for the other two classes of traffic, namely, goods-trains and mineral-trains. Notwithstanding that goods-trains

are run at a lower speed than passenger-trains, yet the coal consumed per train-mile is higher because they have to give precedence to passenger-trains and there is more shunting. In the case of mineral-trains the difference is still more marked, for these have to give way to both the former classes of train. On the Midland railway, the coal used per train-mile in 1892 was only 36 pounds for passenger-trains, but was 53 pounds for goods- and 62 pounds for mineral-trains. To arrive at the consumption per horsepower-hour on the locomotive, which must really form the basis of the comparison, we have to remember that passenger-trains are the lightest and fastest, while mineral-trains are the heaviest and slowest; and that the horsepower is greatest for the former and least for the latter, so that there is really a still greater difference in the consumption per horsepower-hour on the locomotive than is indicated by the above figures. Consequently there is more room for economy in working goods- and mineral-trains than in the case of a passenger service. Of course on railways used exclusively for minerals, the trains would not be subject to the same delay on account of other trains, but still there is liable to be a good deal of shunting, and intervals throughout the day when the locomotives are idle, unless the traffic is very heavy; so that the conditions of working are likely to be far from economical. Besides the question of fuel, there is always the possibility of a lower cost of repairs and renewals, and of a reduction in labour; and, where water-power is available, the coal-bill may, of course, be saved altogether.

Electric power is already in use in many mines for the working of plant below the surface, but so far electrical methods have not been adopted to any large extent for working machinery aboveground, or for the transport of minerals from mines to points where the ordinary systems of transport are in operation. Where electrical methods are already in use it is a simple matter to extend the system, but where this is not the case it becomes necessary to consider rather more carefully whether the advantages of electrical methods can be obtained at a cost which shows a saving over other methods. As the question of cost depends upon the methods used, the output, the locality, the price of fuel, etc., it is best in considering the subject generally, to divide mines into two classes, namely:—(1) Coal-mines; and (2) mines producing minerals other than coal.

## II.—*Coal-mines.*

The chief governing factor in the case of coal-mines is the cheapness of fuel, and therefore efficiency is less important than capital cost. But of course efficiency should not be unduly sacrificed.

*Sidings, etc.*—The amount of coal to be handled may be two or three hundred tons per day or as many thousands. As a rule, however, the railway worked by a colliery consists only of a siding to some previously existing line, sufficient simply for passing the railway-trucks under the hoppers, and for marshalling them into complete trains. Sidings of this kind may be worked, to a large extent, by the gravity method. In some cases, however, a colliery may have to work a line of its own for some distance, either to a railway of the ordinary kind or to a wharf where the coal can be conveniently shipped.

There is some difficulty in the working of sidings electrically on account of the electrical conductors. An earthed return would be used, both for the sake of simplicity and on account of cheapness, so that only a single conductor would be necessary for each track. But, even so, a good deal of complication results on account of points and crossings. Overhead conductors may be used in the same way as for tramways, suitable poles and span-wires being used for their support; but such a method would be very inconvenient in the case of the ordinary trolley, because the pole would have to be swung round before reversing the engine. There is not so much trouble with the bow form of trolley, since the sag of the wire is usually enough to allow of the trolley being pulled to the forward or backward position unless under a point of support. Any difficulty of this kind would be avoided by having conductors near the rail-level forming a "third rail," but then there is a danger that employés may receive rather severe shocks. It is usual to make contact on the upper surface of the third rail, so that the top of the rail is necessarily exposed, and easily touched. If, however, the contact were made at the side, the top might be protected by a wooden covering or otherwise, and shocks avoided, except in cases of the utmost carelessness. As to whether a 500 volts shock is dangerous or not, depends upon the goodness of the contact which is made. In the case of an earthed return, one contact must be made on the ground, or on a running rail,

and another on the third or insulated rail. Both of these contacts must be good for a shock to be severe. If a man's boots or clothing are dry, no appreciable shock is experienced on touching the third rail; but in the case of wet weather, boots and clothing afford little protection. Greater protection would perhaps be obtained by having an insulated, instead of an earthed return. But the cost would be higher and there would be more complication. There would be the further disadvantage that faulty insulation of either rail might cause the other one to be dangerous, and the system might lead to a false idea of security.

Although points and crossings introduce complication, there is no reason why they should cause much difficulty in the electric circuit. The conducting rail must of course be broken at crossings, and since power must be available at all points for shunting operations it is necessary that the locomotive should be provided with double contacts at such a distance apart that any gaps in the conducting rail are bridged. At high speeds, some difficulty might be experienced by contact-shoes being carried away at points of this kind, but this would not arise at the low speeds used on sidings. On the whole, however, it would appear that the advantages are in favour of an overhead system with some suitable form of trolley, no gaps being necessary in the conductor.

In considering the advantages of electric traction, it is necessary to take into account both working costs and capital expenditure. Steam-locomotives work under bad conditions when shunting, because they are inactive during a large portion of their time. The coal-consumption is, therefore, high. Moreover, the cost of repairs and renewals of steam-locomotives is heavy, particularly in work of this kind, on account of the way in which the working parts are exposed to dust. Steam-driven dynamos, on the other hand, may be worked very efficiently, more particularly if used for a number of different purposes, so that the load is fairly constant and the generators are worked at something approaching their full capacity. Stationary boilers have also this advantage, of course, that they can be worked continuously, instead of more or less intermittently as in the case of a locomotive, and may burn a very inferior class of coal if they are fitted with mechanical stokers. The difference in efficiency may be considerable. A steam-locomotive on this kind of work, when its average performance throughout the day is considered, may burn 7 pounds of

coal or more per indicated horsepower-hour, this figure increasing, of course, as its periods of idleness form a larger proportion of the day. In stationary engines, the coal-consumption may be, say, 2 pounds for condensing and 2½ pounds for non-condensing per electric horsepower-hour, that is, at the terminals of the dynamo. Allowing 15 per cent. to cover loss in distribution, and part of the inefficiency of the motors, we have 2·35 pounds and 2·94 pounds respectively as figures equivalent to one indicated horsepower-hour on the locomotive. An electric locomotive used for shunting would not really be so economical as this, because a great deal of the work would consist in starting. Unfortunately there is often a good deal of loss in starting, because energy has to be wasted in the controlling resistances, but since only low speeds and low accelerations are required in this class of work, this loss is not anything like so serious as it would be in locomotives for a passenger-service. If the locomotive be required to haul trains for any considerable distance in addition to the marshalling of trains in the siding, it might be worth while to wind the motors for the higher speed and to use them in series for shunting without going to the parallel position. In this way, the full speed would be reduced to half speed and loss in unnecessary acceleration would be avoided. Allowing for this loss, we may perhaps say that the coal in the case of condensing engines would rise to 3 pounds and for non-condensing engines to 4 pounds. If some length of line has to be served, then the efficiency of both types of locomotives increases, but if the periods of inactivity are more numerous the steam-locomotive becomes less economical, whereas the efficiency of the electric locomotive remains the same. It is apparent, therefore, that the saving in fuel may be very appreciable.

Turning now to capital cost, this would generally be so large as to be unremunerative, if generating plant were installed to deal simply with the traction-requirements of a colliery-siding, because it would have to be large enough to deal effectually with the heaviest load, and at the same time would be worked with a very varying one and a poor load-factor. Electrical methods, however, are being found to be of such value in mining that the case of putting down plant solely for traction would very seldom arise. This is due, of course, to the great flexibility of electrical distribution, combined with an efficiency which is very much higher than that of any other system. Thus, electric haulage is now

frequently used, allowing the most distant parts of a mine to be worked mechanically. Electric coal-cutters may be successfully applied where the conditions of the seams are suitable, though in fiery mines every precaution against sparking must of course be taken. Under these conditions pneumatic coal-cutters may be preferable, as they are free from such danger, and at the same time they afford a certain amount of ventilation. But the inefficiency of compressed air, particularly over long distances, is well known. In such cases, therefore, it will often be found worth while to have an electrically-worked compressor situated in some part of the pit, which is well ventilated, the pneumatic transmission being as short as the conditions will allow.

On the surface, electrical methods have not been used to the same extent as in the workings, probably because the advantage to be gained is not so evident, and, therefore, numerous isolated engines with separate attendants are often to be seen at work at a good distance from each other, with the inevitable long lines of steam-pipes. So far, but little has been done in the way of electric winding. There is no reason, however, why electric motors should not be used for working the remaining machinery, such as ventilating fans, the coal-conveying and screening plant, and the workshops. Electric driving of workshops has been found to be of value in many cases, the extent to which subdivision is carried depending upon the way in which the machines are used. With the usual belt-driving the power used in driving the shafting and belting is generally about 50 per cent. of the whole power supplied. Consequently, a good deal may often be gained by fitting motors to some of the large tools. Of course, the shops of a coal-mine cannot be compared with those of a factory, and fuel being cheap the gain is not so marked, but in any case it will be found worth while to replace steam-driving of the shafting by one or two motors and to centralize the generation of power. The generator installed for that purpose need not equal the aggregate power of the motors, on account of the varying load of each motor. In factories, the maximum load on the generators is only about one half the total possible motor-load, or less. The motors in and about coal-pits, however, have a more steady load and, therefore, the powers of the generators would be a rather larger proportion.

The average extent to which the generators are loaded up, or

the "load-factor" as it is generally called, being high, the cost of generation is low. This has been found to be the case in installations for driving factories. Thus at the works of the Patent Shaft and Axletree Company, at Wednesbury, with an output of 554,000 Board of Trade units per annum and a load-factor of 42·01 per cent., the works cost of generation, namely, coal, water, wages, oil and stores, amounted to 0·552d. per unit.* In the case of a coal-mine with a large output, the load-factor would probably be even higher, with a still lower works cost, and the total, including repairs and renewals, and interest on capital, would not exceed ¾d. per unit.

Assuming then that electrical methods are already in use for other purposes, the extra cost of plant for electric traction is small, say £20 per kilowatt or less. The cost of conductors along the track and bonding would cost perhaps £800 to £1,000 per mile of single track, which figure would be increased in the case of any considerable length of line, on account of feeders. These, however, might be run overhead and would then be comparatively cheap. The locomotives would cost much about the same, whether electric or steam, for work of this kind. Thus electric traction will be advisable if the saving in coal, repairs and labour per annum, is greater than the interest on the outlay required to make the power-house capable of dealing with the traction-load and on that necessary for distribution to the track. Although the value of fuel saved at a coal-pit may be small, on account of the low price of coal, the saving in labour may be important.

Two systems of distribution are at present in use in collieries. The older one of the two is the direct current, which has the advantage to a small extent of simplicity and also that motors so worked may have a very large torque. But it has the disadvantage that sparking occurs at the commutators, which may be dangerous in fiery mines; and further that the commutators are liable to give trouble in positions where there is dust. This last difficulty may, however, be obviated entirely by using well enclosed motors.

The second, and more recent system of distribution is by means of three-phase currents, which have the great advantage that commutators, and therefore sparking, are altogether avoided. On account of this simplification and the increased safety, this

* *Journal of the Institution of Electrical Engineers*, 1901, vol. xxx., page 1,002.

system is likely to displace the direct current in coal-mining. From the point of view of electric traction, however, it is not suitable. The three-phase system is used direct on the motors on certain railways, but it would be preferable to use direct current for this purpose. If three-phase current is being used for the remainder of the plant, in order to avoid the cost of putting in a dynamo which would be worked uneconomically on the traction-load, it would be better to have some of the generators of the double-current type, that is, capable of supplying both direct and three-phase current at the same time. By so doing, an unnecessarily high capacity of plant is avoided and a better load-factor obtained.

### III.—*Mines producing Minerals other than Coal.*

In mines of this kind, the most important conditions are that the output is often relatively small, when compared with a coal-mine, and the cost of fuel may be high. Consequently economy in working costs becomes more important, and the possibility of effecting such an economy by electrical methods is much greater. Not that the actual saving in fuel will be larger, but the monetary value of the saving will be greater and will make it more worth while to invest capital in electric plant.

If the output be small, the railway is likely to be a narrow-gauge one to carry the ore, with or without treatment, in tipping trucks or otherwise, to some point where it can be conveniently handled. It will be desirable, therefore, to keep down the capital outlay in connection with transport as far as possible. If electrical methods are not otherwise employed, it may not be found worth while to put down plant exclusively for traction. But generally speaking, electricity can be applied to so many other purposes in mines, in the same way as in coal-mining, that the plant required for traction would form only a small part of the whole.

*Accumulator-traction.*—Where the traffic is slight, it may be felt that the outlay on conductors along the line is scarcely justified if the railway is of some considerable length. In such a case, use may be made of locomotives worked by accumulators which have the advantage of requiring no connection with the generating station, and are, therefore, cheaper in first cost. The difficulty

experienced with accumulators is that they are not really a mechanical appliance, being far more chemical than mechanical. Consequently, they are generally disliked and seldom understood by the mechanical engineer, with the result that they receive treatment under which they rapidly deteriorate and give dissatisfaction.

Accumulators have now been used on tramways for a good many years with varying success, and as a result it has been found that if high cost of maintenance is to be avoided the cells must not discharge at a very high rate, nor to their full capacity. The first stipulation means that accumulator-traction cannot be sucessfully used on severe gradients, and the second that the battery must be heavy for its work. Thus Mr. Bayet, director of L'Électrique, a company which has successfully worked some tramways on the accumulator-system, allows the batteries to be used to only half their capacity. The weight on that account is apt to be serious in tramway-working, but it is not so important in a railway-locomotive where a certain weight is essential to give the required adhesion for tractive force.

Accumulator-traction has been used on Italian railways and accumulator-locomotives have been employed on both mineral-railways and contractors' lines. It is not suggested that this mode of traction is as satisfactory as the overhead trolley or third rail, but it has certain advantages for light traffic. Not only is the cost of electric conductors and bonding avoided, but the generating plant for supplying a traction-system may be smaller, because batteries can be charged with a smaller current than is required for traction-operations, and they form a constant, and, therefore, an economical, load. In some respects it is best to have the accumulators fixed on the locomotives and charged in position; but as this method is equivalent to keeping capital idle if there is work for the locomotive to be doing, it is better on the whole to have duplicate batteries, so that one that is discharged may be replaced, provided that the means for handling are adequate. Otherwise harm may result.

Unfortunately, the life of an accumulator depends not only upon its construction, but also upon the treatment which it receives. In the case of tramways it has been found that, with proper treatment, the batteries last, according to construction, from about 15,000 to 30,000 car-miles. As the conditions on

light mineral-railways with good level track would probably not be more severe than on tramways, and possibly less so, there is no reason to suppose that the life of accumulators would be shorter. But in any case it would be necessary that the treatment of the cells should be thorough and systematic. From the point of view of labour there is a disadvantage, for accumulator-work is a speciality, and men require a certain training before they can make the necessary repairs and renewals which cannot be carried out by the ordinary fitter.

*Telpherage.*—In mountainous countries, the cost of a railway is often prohibitive if the output is small. In such cases, aerial ropeways are frequently used, and have the great advantage that they are independent of the character of the ground, which may therefore be left undisturbed. The simplest form of ropeway consists essentially of an endless moving rope on which buckets are suspended, but the capacity of this form is rather small. It is more usual to use a fixed rope as a rail and an endless travelling rope to give the required motion. Perhaps the best known ropeway, and one of the longest, is that from the iron-ore mines in the Sierra de Bedar to Garrucha, a port on the sea-coast of Almeria. The total length is 9¾ miles, and is divided into four sections. The first two of these are 1·5 and 2·1 miles respectively and are worked by an engine of 30 horsepower; the second are 3·3 and 2·8 miles, and are worked by an engine of 70 horsepower. The steepest gradient, taking into account the sag in the rope, is 1 in 2½, and the longest span is 918 feet. The buckets each carry a load of 7 cwts., are spaced about 150 feet apart, and travel at the rate of 300 feet per minute, so that the capacity of the line is about 400 tons per day of 10 hours. The contracting engineer, Mr. J. Pohlig, undertook to work the line for 1s. 2½d. per ton carried, his charge covering all costs for labour, maintenance and repairs. Thus the cost per ton-mile would amount to about 1¼d.

Ropeways of this kind have the advantages of simplicity and cheapness, but they have the disadvantages, that the speed is low, that there are miles of moving rope which deteriorates rather rapidly, and that the course must be fairly straight. These defects may be avoided by electrical ropeways, or telpherage, which were originated by Prof. Fleeming Jenkin and Professors Ayrton and Perry. Prof. Jenkin's first idea was to run all the

telphers in series, the same current traversing them all. A single conductor was used and served also as the rail. This was divided into sections equal in length to the trains, so that the current passed from one section to the next through a train, or if no train were bridging the gap, by means of a short-circuit switch. These switches were worked automatically by the trains, but apparently the complication made the system unsatisfactory, and it was abandoned. Prof. Jenkin then developed a parallel system of working, in which only a single rail or conductor was still used. This was divided up into a number of sections equal in length to a train, and alternately positive and negative. The return conductor, available for return traffic, was similarly divided into sections, but the positive and negative sections of the outgoing conductor were opposite the negative and positive sections respectively of the return conductor. All sections of like sign of either conductor were connected together by cross-connections, and on that account the system was known as the "cross-over" system. The trains being as long as a section, were always in contact with two sections of opposite polarity, and thus current was available for the telpher-motor, and was reversed as each section was passed. Thus switches were eliminated, and yet only a single cable was necessary for both rail and conductor for the telphers running in one direction. This ingenious system was working at Glynde, in Sussex, in 1885. Prof. Perry in a lecture at the London Institution in 1886 stated that the cost of transport on this system, including interest and depreciation, varied from about 2¼d. to 3½d. per ton-mile, according to the length of line and the quantity transported.

Since those early days, telpherage has not made much progress, but recently the United Telpherage Company of New York has taken the matter up once more, and now that electric plant is so very much more developed, it is likely that the results will be more successful. In some respects the system which they have adopted is more complicated than the early ones, in that two lines are used instead of one (a trolley-line being used as well as a carrying line), but the latter is simpler, being free from subdivision. The motors work without gearing and take current by means of a trolley, in the same way as a tramcar with an overhead line, the carrying rope being used as a return conductor. Single-motor telphers from ½ horsepower to 6 horsepower weigh from 35 pounds

to 375 pounds, and carry from 25 pounds to 600 pounds. Telphers with double-motor equipment are used from 1½ horsepower up to 8 horsepower, weighing from 125 pounds to 725 pounds, and will carry from 125 pounds up to 1,200 pounds. The working is such that telphers cannot overtake one another, and are used to slow down automatically where necessary.

Among the advantages of telpherage must be included those which generally come from electrical working, namely, the power can be generated where most convenient, and very economically as compared with other methods: particularly when used for several different purposes. In the case of long ropeways worked by steam it may be necessary to supply power at two or more points, for which purpose a separate engine and staff would of course be required at each of these points, leading to uneconomical working. This would be so if the line, even when short, has to be curved to any great extent, but such difficulties are entirely overcome by telpherage. Another advantage is that higher speeds may be used. On ropeways the speed is generally about 3 to 4 miles per hour with the result that the number of buckets on the line is very large. For example, on the Garrucha ropeway the number of buckets on the line at any one time is about 700. On telpherage-lines it appears that the speed has been increased to about 12 miles per hour or from three to four times that on the old ropeways. Thus, the number of buckets for the same carrying capacity would be correspondingly reduced, and assuming that the load per bucket is the same, the line would not need to be so strongly built. As a matter of fact, however, the weight of the buckets would be heavier on account of the motors, so that there would not be a corresponding benefit, at least to the full extent.

As to disadvantages, we have a simple system replaced by one which is more or less complicated. The line has to be so worked that a telpher will not overtake the one in front of it, and the ordinary bucket is replaced by one with an electric motor attached; but, as motors are now made, they may be expected to run with freedom from breakdown and with but little attention. There is, of course, the objection that the dead weight carried is greater, and does not allow the full benefit of increased speed. With regard to the power required, in ordinary ropeways erected over undulating ground a load on a down-gradient to some extent

assists a load on an up-gradient, but in electrical working, power would scarcely be returned to the line, and therefore, apart from other causes, the power required for a given load is likely to be greater. Considering, however, that the total load on the line is less on account of the greater speed and that the power will be generated more economically, it is not unlikely that the running cost may be less. Of course, both systems have advantages and neither can be advocated to the exclusion of the other. On steep gradients, telpherage cannot compete because the telphers would slip, but on moderate gradients and circuitous routes telpherage might afford the only solution, and in many other cases this system might very possibly be used to advantage.

## IV.—*Electric Traction on Roads.*

*Motor-cars.*—In the distribution of goods of one kind or another in towns, motor-car vans are being successfully used, for horse-traction is not a cheap method of transport, as may be seen by inspecting the figures of tramway and omnibus companies. Motor-cars are also being used with success in transporting goods from country-districts to the towns, thus entering into direct competition with the railways; and there is good reason to suppose that this kind of traffic will extend, because the goods are transmitted direct from the producer to the user, instead of passing through two intermediate handlings on the railways with consequent expense and delay. Similar methods might with advantage be used in some case for the transport of minerals, though the field is probably more restricted. Thus colliery-owners would not as a rule profit by a motor-car method, because they load direct into railway-trucks and their customers have their depôts on railway-sidings, so that no handling would be saved. But if colliery-owners also undertook the retail-supply of coal, as they have sometimes done, it would probably be worth their while to use motor-carts; because they would be able to serve a larger area with less labour and at a lower running cost than by horse-vehicles.

Motor-cars worked electrically have not been very successful up to the present, on account of difficulties presented by the accumulator.

In fact, the conditions which have to be aimed at are rather conflicting. From the point of view of efficient running, the dead weight should, of course, be reduced as far as possible. But

from the point of view of durability, the battery should be large, and consequently heavy, for the work which it has to do, as it should never be used to its full capacity. This has been found to be essential in tramway work.

Table I. records the weights of batteries used by various companies on their accumulator-tramcars. From these figures it will be seen that the battery generally forms a large proportion of the weight, unless the distance run is short, as at Dunkirk, where the distance varies from about 12 to 15 miles.

TABLE I.—WEIGHTS OF ACCUMULATOR TRAM-CARS AND BATTERIES.

| Name of Company. | Weight of Car complete. Tons. | Weight of Battery. Tons |
|---|---|---|
| Compagnie Générale de Traction, Paris | 16 | 4·0 |
| Tudor Company | 14 | 3·4 |
| Do. | 15 | 3·9 |
| Ostend | 13 | 2·0 |
| Ghent | 13 | 2·0 |
| Dunkirk | 11 | 1·0 |

Of course, the conditions of road-traction and tramway-traction are very different. A road-vehicle is necessarily very much lighter, and on that account the weight of the battery would be reduced compared with the weights given above; but, on the other hand, the surface of even a good road is rough compared with a rail, so that the tractive force is greater. Moreover, the state of the roads varies very much according to the weather, and the maximum distance that a car can safely run without re-charging has to be greater than on a tramway, so that the battery must be large enough to allow for the maximum distance when the roads are in bad condition and for the severest gradients. The weight must also depend upon the general character of the country, whether hilly or otherwise.

The weight, however, would not be such a serious matter if the life of a battery were long. Unfortunately this is not the case. On tramways, the cost of renewing batteries varies a great deal. The lowest cost of renewals that has come to the knowledge of the author is 0·45d. per car-mile, while the lowest figures for maintenance, renewals and handling for charging is about 1d. For a car running on ordinary roads the cost would no doubt be a good deal higher, because the greater vibration would be liable to damage the cells mechanically, and the conditions are also more severe on account of gradients.

*Trolley-lines.*—In order to avoid the difficulties that are introduced by accumulator road-traction pure and simple, several attempts have been made to use an overhead-trolley line for supplying the power to road-cars. Of course, such methods lose the freedom possessed by a motor-car, as only a definite route can be followed, but they have the advantage that the cost of running is low, and, as compared with a tramway, the capital cost is less because track is avoided. Of course, for mineral traffic, a system of this kind could only be run on a private road, and then it would be necessary to consider whether the maintenance of an ordinary road would cost more or less than that of the track together with the interest on the capital invested in it. The result would depend on the amount of traffic.

Distribution by an overhead line in this way is rather more complicated than on tramways, because the earth is not available as a return, and therefore two wires must be used. Road-cars fitted with two trolley-poles, rather longer than those used on tramcars, each in contact with one of the overhead wires, have been tried with some success in Germany. This arrangement is simple, but it does not allow of very much lateral movement to get out of the way of other vehicles. When the traffic is small it may work satisfactorily.

Another method is to have a trolley running on the two overhead wires in much the same way as a carrier runs on a double ropeway. This trolley makes the necessary contacts, and is connected to the car by means of a flexible cable which pulls it along. The difficulty experienced with this arrangement is that the cable is likely to sag very much when the car comes to rest, thus being dangerous to other vehicles; and that when the car moves for any reason to one side or the other, the pull is no longer in the line of motion and the trolley is likely to foul the overhead wires. Otherwise it is satisfactory, as regards freedom of movement.

In order to overcome this difficulty Mr. Lombard-Gerin has introduced a motor-trolley capable of running without any pull being exerted on the cable. The trolley is fitted with a small three-phase motor, and is connected to the car by a flexible cable consisting of five conducting wires. Two of these carry the current from the overhead lines to the car-motor. This motor is so made that it can give three-phase current when in motion, and this current is transmitted by the other wires of the cable to the

three-phase motor on the trolley. Since the latter runs synchronously with the car-motor, it adjusts itself automatically to the speed of the car; and it is so made that the trolley tends to travel faster than the car, with the result that it is always in advance and there is a certain tension on the cable.

The weight of the trolley being 55 pounds, the overhead line has to be stronger than for the usual tramways and has to be supported every 90 feet. But if wooden poles are used, such a line can be constructed for about £750 per mile, which is a comparatively small amount. Of course the energy required to propel such road-vehicles is about double that taken by cars running on rails, and the capacity would generally be less, but under certain conditions the system is no doubt worthy of attention.

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Mr. R. Hood Haggie (Derby) wrote that Mr. Cooper pointed out that the saving of fuel at collieries was not considered so much as it should be where fuel had to be purchased, but now-a-days, when all classes of coal were marketable, there was no doubt but that colliery-owners and managers would economize in every possible direction. The saving in working-cost was undoubted when electricity could be used, taken from a main generating-station fitted with most economical machinery, in the place of small engines and boilers, especially when the load was intermittent as in the case of shunting-engines.

Mr. Cooper had referred to the difficulty of reversing the motor, except by turning the trolley-pole, but this could easily be overcome by a reversing-switch on the engine and points on the overhead-conductors, as on many tramway systems in towns, these points might be made movable only in conjunction with the rail-points. Of course this reversing-switch would only be used when shunting, and necessarily going at a slow speed so that the trolley would easily take the points on the overhead conductors when running backward; but when the engineman was ready for a long run, say to the main line, he would turn the trolley-pole. This system would be greatly simplified by using one overhead conductor for three parallel lines, as the trolley would easily swing out that distance to the centre of the middle pair.

In comparing three-phase and direct-current motors, Mr. Cooper laid particular stress upon the great advantage of there

being no commutators on three-phase motors, though with modern practice in building electrical machinery, the greatest danger did not lie in this, but in the possibility of a spark from a broken cable and in the jeopardy to life from shock. The chance of broken cables was the same in both systems, except that there were three cables in the one case and two in the other, but the danger to life was acknowledged to be greater in the case of an alternating-current shock, as it was almost impossible for a man to withdraw from such a shock as each alternation seemed to cause a further contraction of the muscles.

The writer rightly pointed out also that direct-current motors were preferable for locomotives on account of the superior starting torque, but he advocated three-phase for all other motors, whereas in the majority of motors at a colliery, great starting torque was necessary or at any rate an advantage, for example, in driving pumps where there was a long rising-main and the pump was required to start against the full head. Again in both main-and-tail-rope and main-rope haulages it would be a disadvantage to keep the motor running constantly where there was a long wait between the hooking-on and detaching of the empty and full tubs; and, lastly in coal-cutters either for undercutting longwalls or headings, the former especially hardly ever started without having the full load of the motor against them and often with the discs or bars firmly embedded in the seam so that more than the normal load of the motor was required to start them. Therefore on this showing, the direct current had a decided advantage. Undoubtedly in many cases the three-phase system was advantageous. For instance, in long distances between the generating-station and the motors it was an advantage to be able to run at a very high voltage and so reduce the initial cost in the mains, and at the other end this high voltage could be transformed to a more easily handled voltage and then transformed again to direct current for motors.

Undoubtedly, many collieries could adopt the overhead-trolley system for shunting, with decided advantage to themselves, but in most cases the initial cost frightened managers.

Mr. C. C. Leach (Seghill) said that many of the powers used about the pit were very small, thus the ordinary shop-engine did not exceed 30 horsepower, and any saving would be infinitesimal.

One advantage with ordinary steam-engines and steam-pipes about the pit was that if any little matter went wrong it was readily put right without stopping work. It was one of the ordinary difficulties of pit-work that nothing could be delayed without great loss.

Prof. CARUS-WILSON (London) remarked that the various proposals for power distributing schemes emphasized the importance of utilizing electricity for haulage, and although the author did not specially deal with haulage underground, it was proper to include in the term electric haulage, both underground and for surface-work. The trolley-line was undoubtedly the simplest method of dealing with electric haulage, but the great difficulty as regards underground work was the danger of sparking on the trolley, and therefore the only method, other than that of accumulators, which was unsatisfactory, was to utilize the existing rope-arrangement, and drive the rope-gear by electric motors. He agreed with Mr. Cooper that the continuous-current motor was the most satisfactory for that purpose, but there was the difficulty of sparking, so they were obliged to use an alternating-current motor, which did not spark. Such motors had to be of the closed type, where no starting rheostat was used; and these motors did not give such satisfactory results as those that could be used with a starting rheostat. The practical outcome of this was that they must use some form of clutch; but when electricity was introduced into a mine, the manager often wanted to get rid of all apparatus such as clutches, and expected the motor to do everything which was formerly done by steam-engines with clutches. He came across a case a short time ago, where a difficulty was raised as to the performance of the motor. According to specification it had to run 12 loaded trucks 4 miles an hour on a level track in the mine. It would do this perfectly well, but there was a difficulty in starting without the use of a clutch, notwithstanding that the motor was of 40 horsepower of the best make, and that the whole of the trucks could be easily started and moved by a single horse. The moral was, not that electric haulage was deficient, but that the system of rope-transmission was lamentably inefficient. As long as a rope-haulage system was run by a steam-engine, no notice was taken of its inefficiency, but when it was run by electricity all sort of enquiries were made. When

electricity came to be introduced into mines, defects were often attributed to the electric system which were really due to the existing system of rope-transmission.

Mr. SYDNEY F. WALKER (London) pointed out that electricity was already largely employed in mines in this country, both underground and on the surface. Of course, it was first used underground on account of the convenience it afforded, and it was gradually extended to surface-work. The principal causes of failure were that the installation was erected of insufficient power. The installation was erected to do a certain piece of work; then it was found convenient to take a wire from it to work something else, and as the current was so handy various little demands were made upon it, until it was found that the original power was insufficient for all requirements. There were a large number of three-phase motors working successfully underground, but of course a starting resistance was necessary, although this could be boxed-in as much as was desired. With the commutator of a continuous-current machine, they could not prevent sparking under the best conditions, and therefore it was necessary to have an enclosed motor. The conditions underground were very variable, and therefore the motor did not work under the best conditions. The great danger in the transmission of power was from the breakage of cables, though this could be considerably minimized by care. As the distances became greater and the haulage longer, the power to be supplied at long distances was very much greater, and the cables enormously thick. He had recently been advising upon an installation at a Yorkshire colliery, where they had made a bold departure and put down 2,000 volts to be taken down the pit with the primary cables to be hung in the main intake airway. This was transformed to 100 volts for actual haulage. There were several haulage-planes, and he considered that this system properly carried out would be safer than the existing 500 volts method. In addition to the danger of sparking, the trolley method with electric locomotives was not suitable for mines, because of the switchback character of the roads, and the locomotive would not work well under these conditions from overhead conductors, the conditions being such as to produce frequent sparking. On the Continent, an accumulator-locomotive had been introduced, and one was shown at the Glasgow

Exhibition which had been in use for 2 years in Westphalia. He examined the accumulators, and they appeared to be in good condition. Many collieries were fitted up with ordinary safety-lamps lighted by an electric spark, and the heating arrangement was worked from electric accumulators charged at the colliery. Numbers of men were therefore becoming accustomed to the handling of the accumulators, and it would only need a little explanation to enable them to handle the accumulators that would be used for electric locomotives of this kind. He ventured to think that the time was not far distant when accumulator-locomotives would be used for underground work. The conditions for charging accumulators were very different from what they were a few years ago: and they could now be charged in 3 hours, while formerly at least 8 hours were required. With reference to the case mentioned by the previous speaker, where a 40 horsepower motor would not start, this was possibly due to some little fault which might easily have been put right. Thus, if it were a three-phase motor, it might simply be short-circuited; or possibly, the conditions were such that it could not exert sufficient torque, but there was no difficulty in providing a sufficient resistance. He ventured to suggest to electrical engineers interested in mining work that, if the advocates of compressed air were to go in for high pressures, they would give electrical men a rather bad "tying up."

Mr. A. S. E. Ackermann (London) said that he had recently been in the United States for about 4 months giving attention to the question of mechanical coal-cutting and haulage. He had visited 21 mines, in all of which mechanical haulage of one kind or other was invariably adopted: usually the overhead trolley system of electric traction; in some cases with a single wire, and in others with a copper return-wire. In one case, he found that the copper return-wire was simply laid on the thill, as it saved the expense of fixing it up, and there was less chance of a short circuit in case of a fall of stone. In one instance, he saw a man, leaving a mine, touch a trolley-wire with his cheek, the wire hanging low owing to a recent fall of roof. The pressure was only 250 volts, but the man was knocked down, though he was up again in a quarter of a minute. He had read of an installation, but did not see it, where the third-rail system was adopted, and anybody could

stand on both the live conductor and the return rail. The attention of an official was drawn to this and he replied "Well, it may be a bit dangerous, but if a man has not the sense to keep off the third rail, then America has no use for him." America did not so often take the lead; she simply adopted readily and on a large scale what our scientists and inventors discovered and produced. Great Britain seemed to be taking the lead in regard to three-phase current work: he only found it being used in one mine for driving pumps. It was not used for working haulage-motors. In one set of mines, the largest that he visited, and belonging to one of the greatest companies in the States, not a single horse or mule was employed in the mine, the whole of the work being done by electric-trolley haulage. There was plenty of sparking, but the mines seemed to be free from gas, and to a certain extent, no doubt, they were willing to run risks there that would not pass muster in this country.

The PRESIDENT (Mr. J. S. Dixon) remarked that there seemed to be an erroneous impression with regard to the use of electricity in this country. In Scotland, it was used in everyday practice: half the haulage in the Hamilton district was done by electricity, and it was all done by clutches. At his own colliery, there were four haulage-planes driven by one motor; and these were all thrown off and on, as required, by clutches. He did not know of any place in Scotland where electric locomotives were used, and he did not see how they could deal with large quantities of coal by that method. In his address, he had mentioned an instance where 800 tons per day were hauled by a single rope, and with a tub at every 10 feet of rope, they could deliver more material than any system of locomotives. He thought that electrically-driven rope-haulage was the best system for dealing with large quantities; and it was also the most economical. With precautions against sparking, there was not much danger, and by using carbon-brushes this was reduced to a minimum.

Mr. A. S. E. ACKERMANN stated that he did not see any case in the United States where electric power was used to drive a rope-haulage. In one instance, 2,000 tons per day were brought out on a double way from a drift-mine worked on the trolley-system at 550 volts. The tubs held 2,500 pounds of coal and weighed about 11 cwts. themselves. Nearly all the other cases of

nechanical haulage which he had seen were of the pneumatic ocomotive type. The receivers of the locomotives took air at 750 ounds per square inch, and this was reduced to 150 pounds per quare inch before it entered the cylinders. The pneumatic and lectric locomotives ran at about the same speed, namely, from to 10 miles per hour.

The PRESIDENT (Mr. J. S. Dixon) remarked that this quantity ould not have been produced with the 10 cwts. tubs used in cottish coal-mines. He had pleasure in proposing a vote of hanks to Mr. Cooper for his interesting and instructive paper.

Mr. S. F. WALKER, seconded the resolution, which was cordi- lly approved.

Mr. W. R. COOPER (London), replying to the discussion, said hat he had not meant to convey the impression that electrical nethods were not used largely in mines; his remarks referred ather to electrical power for haulage aboveground.

For surface-work, the advantages of electric working were not o obvious, and the gain was often due chiefly to a saving in labour. This would be so in the case of shop-driving in many cases. If hops were small, it might not be worth while to put in electric driving; but there was always the advantage that, if the machines were properly grouped, there was a saving in wear-and-tear. The whole subject of electrical working had become much more mportant since the advent of large power companies, because the uestion of generation was, of course, avoided by taking such a upply, and small installations which might demand rather a eavy capital outlay could be worked profitably. This was the ase, for instance with a traction-load on a short line.

Referring to the remarks of Mr. Haggie, a trolley-wheel did ot introduce any difficulty so far as the motor was concerned, as t ran independently of the direction of the trolley-pole, but the heel would be troublesome if it were run backwards at points, nd therefore the bow form was more suitable. With regard to notors, there was complication in using a three-phase system for raction, but the torque was sufficient for most purposes.

Generally, it would not pay to transform from high-tension hree-phase to direct current, for this would involve the use of otary converters; it was better to avoid plant of that kind if ossible, as it required attention.

Accumulator-locomotives would certainly be useful if otherwise satisfactory, and they could be charged in much less time than that mentioned by Mr. Walker. On tramways, accumulators were often charged in ½ hour, although slow charging was better for the cells and gave a better load for the generating plant.

The difficulty mentioned by Prof. Carus-Wilson, as to the amount of power required, was one that was frequently experienced, for there seemed to be a great deal of ignorance as to the power taken by steam-driven plant.

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Mr. G. P. Lishman's paper on "The Analytical Valuation of Gas-coals" was read as follows:—

# THE ANALYTICAL VALUATION OF GAS-COALS.

By G. P. LISHMAN, B.Sc. (Edin.), F.I.C.

*Introduction.*—In the seventeenth and eighteenth centuries destructive distillation was the commonest process in use in chemical laboratories. Nearly everything was distilled from green glass, earthenware or iron retorts at various temperatures, a cooled tube or globe being used to condense the products, even vipers are stated to have been "analysed" in this manner. As regards coal, the first recorded quantitative experiment was one by Stephen Hales, who, in 1726, obtained from 158 grains of pit-coal 180 cubic inches of gas, equal to a yield of 10,340 cubic feet per ton, probably a very accurate result.

It was about the beginning of the nineteenth century that gas-lighting began to be introduced into this country. In 1820, London had some 4,000 burners; and no doubt gas-makers would, at an early stage, develop methods of distinguishing between good and bad coal. From the fact, however, that there is an almost total absence in scientific journals of papers on the testing of gas-coal, we may gather that the subject has been somewhat neglected. This has been largely due no doubt to the very considerable expense involved. The result has been that although coal-testing plants are attached to most gas-works now, they are usually of but limited use to the engineer, who still has to rely mainly on his working-scale results.

When coals are tested under the usual conditions, the results, expressed in cubic feet per ton and candlepower, come out most irregularly, and very considerable differences are found between one test and the next.

*Nature of the Difficulties.*—The cause of this trouble is to be found in the extremely complicated nature of the chemical reactions taking place in the retorts, and the physical changes occurring in the condensers of the plant while coal is being dis-

tilled. Prof. Mills has enumerated some 101 products resultin[illegible] from the distillation of coal, and has given their boiling points [illegible] 0·1 per cent. (more or less) of some of them in the resulting gas wi[illegible] make 0·1 candle difference in the illuminating power. If the reto[illegible] be a few degrees hotter than usual, the heavy hydrocarbons [illegible] illuminating constituents of the crude gas are broken down in[illegible] simpler bodies, such as methane, ethane, etc., containing le[illegible] carbon and therefore of less illuminating value. The carbo[illegible] thus separated is deposited in the retorts as "retort-carbon."

In the condensers, the changes taking place are more of physical than a chemical nature, but are no less certain to cau[illegible] fluctuations in the illuminating power, if their temperature [illegible] not kept constant. The function of the condensers is to remo[illegible] from the gas all tarry matters which might cause trouble throu[illegible] stoppages in the mains. These same 101 products, which ha[illegible] their boiling points, have also their dew points, at which they co[illegible] dense from the gas, and if the condensers be a few degre[illegible] colder or the gas perhaps be travelling through them a little mo[illegible] slowly than usual, more benzol, say, will be condensed and t[illegible] illuminating power of the finished gas will be reduced; whi[illegible] under contrary conditions the reverse will be the case.

In fact, the main cause of the difficulties of coal-testing [illegible] experimental plants may be summed up in the word "temper[illegible]ture;" and in this respect, a small apparatus is much more readi[illegible] affected by external conditions than a large one. In a wor[illegible] where there are many retorts, irregular gas coming from o[illegible] quarter will be compensated for by that from another a[illegible] "corrected" by this means, so that the result is a more or l[illegible] uniform product from day to day.

Very slight differences of temperature in the condensers m[illegible] make a considerable difference in the quality of the gas produc[illegible], and if we can overcome this it ends the difficulty from the po[illegible] of view of the gas-engineer, who has only himself to consider. [illegible] to him it does not matter whether the results from the testi[illegible] plant are higher or lower, within limits, than those obtained [illegible] the works, so long as they are reliably comparative. This las[illegible] the desideratum, which, so far, has been so difficult to obtain [illegible] any method that may reasonably be called a laboratory one.

The analytical chemist, however, is confronted with the furt[illegible] difficulty, that from the same coal a better result will be obtain[illegible]

n one gas-works than in another: this variation being caused oth by differences of efficiency in the plant used, and by the per- onal equation of the gas-engineer. There is a point in steam-coal nalysis exactly analogous to this; the actual evaporative power f a steam-coal varies according to the boiler used, but we over- ome this by giving always the theoretical evaporative power hich would be obtained were the coal perfectly burnt and the eat entirely used for evaporation. The comparative figures btained in this way, though higher than those got on the work- ng scale, represent an absolute property of the coal, assume othing, and are useful. But this cannot be done with gas-coal; nd, even if it could, would not be desirable. It is not advisable, ecause we cannot obtain on the testing-scale as high results in inter as we do in summer, or in summer here as high results as ould probably be got in summer in the south of France. For esting-purposes, the upper limit of the sperm-value is exceed- ngly high, and long before it is reached the conditions under hich we are working become quite abnormal. Gas-results, it is ow generally considered, must be reported in terms of what could e obtained from the coal, on a working scale, by a capable gas- ngineer using an efficient gas-plant.

*Attempt by Means of a Standard Apparatus.*—The difficulties s above detailed fall naturally under two heads, namely:—(1) Those connected with the temperature of the retorts and of the ondensers; and (2) that due to the difference of results found in he various gas-works. Keeping these in view, various methods ave been tried at Lambton for overcoming them, and for finding a neans of testing gas-coals on the laboratory-scale. Some years go, it was thought that it might be possible to produce a standard pparatus, in which, by warming the condensers in cold weather nd by other devices, the evil effects of winter-days might be bviated. The condensers were water-jacketed and kept always t 70° Fahr., and sometimes sections of them were bye-passed. This produced a slight improvement, but it was found that even hen bye-passing the whole of the condensers, the mass-action of he cold pipes and purifiers on the slowly-passing gas caused much lower results to be obtained in winter than in summer. More- over, this left the vagaries arising from variations in retort- temperature quite out of the question. It had been hoped to avoid

these variations by means of a mercury governor on the gas-supply which heated the retort, but this expectation was not realized. It is easy to lay down ideal conditions which are always to obtain when tests are being made, but it has been found quite impossible to realize them in daily work.

These experiments, extending over twelve months, although failing in their primary object, or rather shewing that it was unattainable, were of value as indicating two points, namely:— (1) That in any apparatus designed for coal-testing the amount of condensation must be capable of very considerable variation indeed; and (2) that in successive tests on the same coal the results are more constant when the condensation is rather heavy.

*Apparatus used.*—In considering the design of a coal-testing plant it is necessary to bear in mind that we cannot make our apparatus a model of a full-sized gas-works, for no two works are alike. At the same time, we must retain the same general outlines consisting of retort, ascension-pipe, condensers, preferably a scrubber, purifiers and gas-holders. We must also use a sufficient quantity of coal to make at least 8 cubic feet of gas, as that is the least quantity with which the illuminating-power can be satisfactorily taken.

By using a standard coal as described below, to correct for varied condensation, we do away with the necessity for adhering rigidly to one particular form of apparatus, but certain essentials cannot be neglected, particularly when work is to be done in all weathers. These may be stated as follows:—

(1) The condensers must be much larger, in comparison with the retort, than those used in gas-works. They must be water-jacketed for cooling in summer, and so arranged that they may be bye-passed in sections.

(2) The purifying area must also be larger, in comparison with the retort, than is the case in gas-works, so that in a considerable series of tests approximately the same conditions as to purification may obtain throughout.

(3) Two gas-holders, conveniently each of 15 cubic feet capacity, must be in use, so that tests may follow immediately one upon the other, and the temperature of the retort may be thus maintained the same during each experiment.

(4) The whole arrangement must be placed indoors, and in

summer the heat from the retort must be kept away from the rest of the plant.

(5) A good photometer and spacious photometer-room are also necessary. As regards this part of the subject, it will be enough to say that although the illuminating power of a gas is in this country always stated as being of so many candles, the use of the candle as a standard of light in actual photometry has been widely discontinued, the Harcourt 10 candle pentane lamp or the Methven screen being used in its place.

The general arrangement of the plant at Lambton is shewn in Figs. 1 and 2 (Plate XXVIII.).

*Routine Details of a Test.*—One-thousandth of a ton or 2·24 pounds of coal has been found a convenient and sufficient quantity to take for a test: about 10 cubic feet of gas are obtained, an amount which is ample for taking the illuminating power, but if the coal gives a poor yield a larger quantity may be taken. The coal is charged into the red-hot retort in a sheet-iron box, measuring 14 inches by 4½ inches by 2 inches, and the door, carrying its fire-clay luting, is screwed tight. The tap, at the entrance to the gas-holder, is immediately opened. In from 60 to 90 minutes, the gas will have ceased to come off; the volume is then measured, and the retort discharged. The gas is next passed into the other holder, being thus properly mixed, and on to the photometer to be burnt there. The retort is at once ready for the succeeding charge, which is worked into the first holder as before, the illuminating power of the gas from the previous test being taken in the meantime.

*Use of a Standard Coal-seam.*—We have seen that it is not by any particular form of apparatus alone that gas-coals can be satisfactorily valued; and as it is undesirable for statements as to their quality to vary on account of the season of the year in which the tests are made, it becomes evident that some correction must be applied to the results actually obtained before they can be accepted as true. "Corrections" in general are largely used in analytical chemistry, and indeed run all through practical science: for instance, the volume of a gas has always to be corrected for the temperature and pressure at which the observation is

made. So there can be no objection to the method as such, it is only necessary that we should determine, on any particular day, the proper correction, and that it be maintained at a fairly small percentage of the final result.

In the case of coal, the correction is found by using a coal of known value. A standard coal has been used before, and is probably in use now in places, at any rate the idea is by no means novel, but its adoption is not at all general. Moreover, a ton of coals may be useful as a standard for a series of tests extending over one or two months, but the coal itself will begin to change after this time, and for continuous work no standard except a standard seam can be of any value.

At the Lambton collieries, there is a seam, which, within a certain area, is very fairly constant in quality, and the sperm-value* of this coal is fixed at a figure obtainable from it at any of the best gas-works. It is stored in small stocks at a time at the laboratories, so as to be always fresh. Anyone near a coal-mine can with some little difficulty obtain a standard coal, but it is necessary to know the coal well and to exercise care in its selection.

In testing an unknown coal, two blank charges are first worked through the apparatus, and the volume of gas obtained in these may be noted, but this gas is burnt away at the photometer without being tested. These preliminary charges are merely made so as to secure that the pipes, purifiers, etc., of the apparatus shall be full of ordinary "end-gas" or "last runnings."

Three consecutive tests are then made:—(1) Coal to be tested, (2) standard coal, and (3) coal to be tested, the yield being noted and the illuminating power taken in each case; and from these we calculate the sperm-value. Working in this manner we find out every day what a coal of known quality is doing, and the unknown is corrected proportionately. On a frosty day, for example, when condensation is unavoidably severe, condensers are short-circuited, but still the sperm-values come out as low as perhaps 490 or

* The gas referees' standard candle burns 120 grains, or $\frac{1}{7\frac{3}{5}}$ pound of sperm per hour. Gas is burnt at the rate of 5 cubic feet per hour when being tested, so that the number of feet made per ton must be divided by 5 to reduce them to their equivalent in lighting units; and this number multiplied by the candle-power, and the product by $\frac{1}{7\frac{3}{5}}$ (pound of sperm burnt per candle per hour) gives the illuminating value of the coal per ton in pounds of sperm, which is shortly called the "sperm-value." Practically, the sperm-value equals the yield of gas in cubic feet per ton, multiplied by the illuminating power in standard candles and by 0·00343.

00 pounds per ton from good coal, the standard being also affected n the same manner. And this coal which in August would give a perm-value of 600 pounds per ton will now only give 520 pounds. The value which can be got out of it in a first-class works is, say, 80 pounds, therefore the value of the unknown coal is found by he proportion, as 520 : 580 = 495 : to the corrected sperm-value n pounds per ton.

It will now be seen that, when it is said that a coal has given in . testing-plant results equal to "10,000 cubic feet of 16 candle-ower gas," that is, a sperm-value of 548 pounds per ton, the state-nent as it stands is flexible, and that these 548 pounds, while ctually obtained and possibly regularly obtained, may really equire to be corrected down to 500 pounds before arriving at a igure which could be got from the coal at any gas-works in the ountry.

But as a rule, we have had, at Lambton, little success in correct-ng down, and we find that somewhat heavy condensation (which of ourse reduces the illuminating power) has a considerable steady-ing effect on the gas, and on the result, which may then by means of the standard be corrected up to its true value. The most satis-factory tests are those in which the standard coal is giving a sperm-value from 20 to 40 pounds below its fixed figure, and as far as can e done the condensers are manipulated so as to secure this result.

*Advantages.*—(1) It will be seen that the practice of this method onsiderably minimizes the difficulties due to variable condensa-ion. By the use of water-jacketing, there is little difficulty n maintaining the condensers at a constant temperature through-ut one day, and one day is all that is necessary, as the correction an again be found on another day.

(2) It is less difficult to keep the retort-temperature constant for ne day, than to maintain it at the same temperature on different lays.

(3) The analyst's difficulty, caused by the variety of results btained from the same coal in different gas-works, is largely vercome, because the standard coal is fixed at a sperm-value which can be obtained from it at our best gas-works, and all orrected results are statements of what can be obtained from the oal at such works.

(4) The method permits of the alteration of the form of the

apparatus, from time to time, as improvements may be suggested, for such alterations affect only the uncorrected results.

*Conclusion.*—By means of proper condensation, the use of a coal-seam as a standard, and careful attention to retort-heat, gas-coals can be somewhat finely discriminated by a laboratory method; and the use of a standard coal is regarded as absolutely essential to success.

The writer's thanks are due to the Lambton Collieries, Limited, for having, during several years, supplied the expensive apparatus necessary for the various experiments which have been carried out, and to Mr. C. W. Martin for the constant interest which he has taken in the progress of the work during that time.

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DESCRIPTION OF PLATE XXVIII.

*A*, retort, heated by gas. The short bent pipe prevents excessive dripping of tar into the retort. Tar condensing in the ascension-pipe is caught in the seal-pot, *B*.

*C* and *D*, condensers, carrying cocks by means of which 1, 2, 3, 4, 5 or 6 tubes may be used at will, or the whole bye-passed. The condensers are carried in water-tanks, through which a constant stream of water may be kept running to secure an even temperature. This circulation is only necessary in hot weather, but the tanks are always kept full of water.

The spout under the seal-pots, *E* and *F*, carries tar and liquor into the tar-pit, *G*.

*H*, scrubber, containing wet glass-marbles, and it can be bye-passed at will.

*I* and *I*, purifiers, one of which only is used at a time.

*J* and *K*, gasometers.

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The PRESIDENT moved a vote of thanks to Mr. Lishman for his interesting paper.

Mr. GEORGE MAY seconded the resolution, which was cordially approved.

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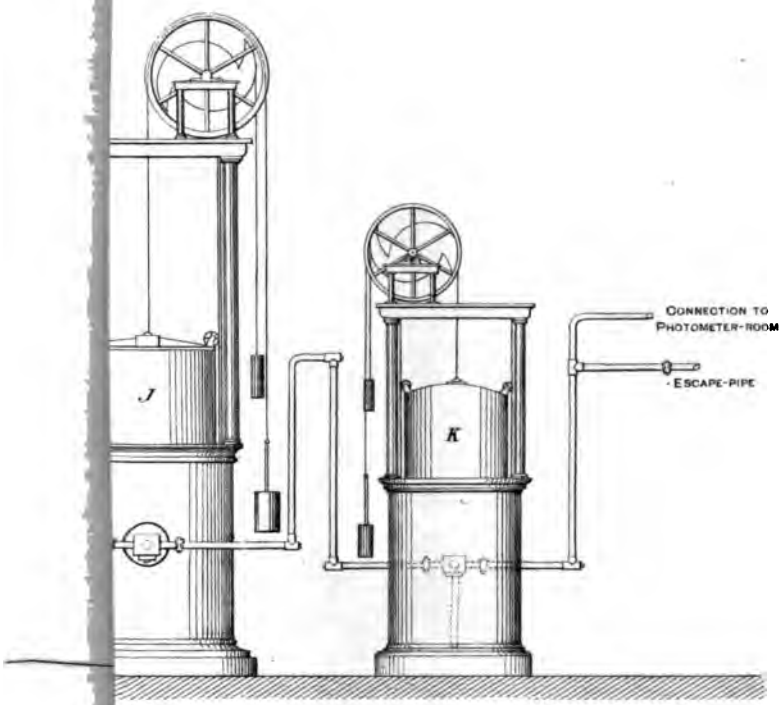
Mr. DUNBAR D. SCOTT's paper on "Mine-surveying Instruments" was read as follows:—


CONNECTION TO PHOTOMETER-ROOM
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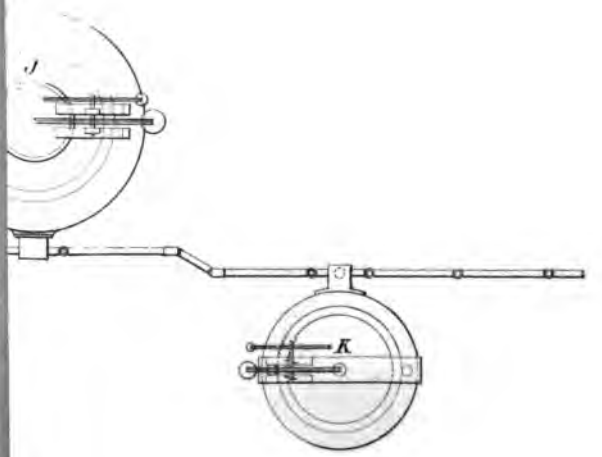
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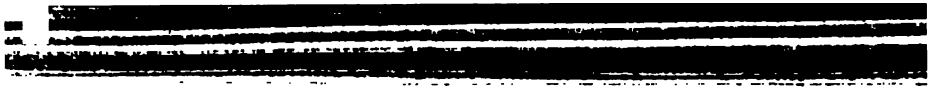


# MINE-SURVEYING INSTRUMENTS.

By DUNBAR D. SCOTT.

*Introduction.*—Perhaps Mr. H. D. Hoskold's casual reference to the instrument associated with the writer's name* will be considered sufficient excuse for him to give a more extensive account of its design and applicability in mine-surveying, and indeed to introduce some of the other instruments that have been used in the United States since mining became an industry second only in importance to agriculture. It was not his intention to discuss the entire subject-matter of Mr. Hoskold's paper, for he did not profess to be a geodetic engineer nor an archæologist; and what retrospective information he had been able to collect along these lines was nearly exhausted in a paper communicated four years ago to the American Institute of Mining Engineers.†

The republication of quaint old instruments is an attractive diversion, but cannot be seriously considered as essential in the education of the young engineer. It serves, chiefly, the purpose of satisfying his curiosity and fixing in his mind the salient points in the history of this branch of mining engineering, as well as of establishing an authenticated record, which impostors may not disregard. As an instance, a firm may be cited, who have had the temerity to announce in their catalogue the adoption of a new formula by which they had overcome chromatic aberration—a statement that would tend to establish the confidence and increase of trade, which they sought, with those who did not know of the famous publication of John Dollond,‡ whose discovery is said to be consequent upon that of Chester Moor Hall in 1733.

* *Trans. Inst. M.E.*, 1900, vol. xix., page 217.

† The reader, who wishes to further pursue this general topic, is referred to vols. xxviii., xxix., xxx. and xxxi. of the *Transactions of the American Institute of Mining Engineers*. The original paper on "The Evolution of Mine-surveying Instruments," together with twenty contributions from engineers resident in various parts of the world, is now published, by that Institute, in a separate small volume.

‡ *Philosophical Transactions*, 1758, vol. xi., page 267; and also Peter Dollond, *Ibid.*, 1765, vol. xii., page 194.

Development in instrumental construction had been very gradual, and engineering methods had been deliberate in their advance to the present state of perfection, the errors, ignorance and prejudices of the old-time authorities having been transmitted through generations from instructor to novice. There have been very few sudden and far-reaching reforms.

If one desires to become a student in this branch of classified knowledge, he must delve in musty records and books that have a value principally on account of their age. Upon this pretext, in addition to his previously avowed intention, the writer picked up the thread of Mr. Hoskold's argument without any professed attempt, or desire, to make a complete review of any of the topics touched upon.

*Quadrant.*—Mr. Hoskold leaves his readers with the impression that mine-surveying began with the magnetic needle, in some form; but Beyer says "there can be no doubt that, from the earliest times down to about the end of the fourteenth century, mine-surveying was conducted (on the Continent at any rate) almost wholly by use of the quadrant, when it was, to some extent, replaced by the setz-compass."* The most substantial evidence of this fact is contained in the works of Dr. Reinhold† where the use of the quadrant (Fig. 1), in taking both horizontal and vertical angles, is fully explained. His polite apology for the publication of the mine-surveyor's art was founded principally upon the fact that it had been kept a secret too long. His desire to propagate it among practical miners had the recognition of the Emperor Maximilian. He gives a short treatise on levelling, both by the ancient water-trough system, sometimes called a diopter, and the graduated semicircle with its plummet; he explains the co-ordinate system of plotting, and actually introduces a lucid treatment of trigonometrical calculation after Regiomontanus (1436 to 1476), the celebrated mathematician and Bishop of Ratisbon.

In consequence, the 85 pages in Dr. Reinhold's work, devoted to mine-surveying, the writer believes, should be regarded as the first comprehensive and instructive treatise on the subject. True,

* *Gründlicher Unterricht vom Bergbau nach Anleitung der Markscheidekunst*, August Beyer, Schneeberg and Altenberg, 1749.

† *Gründlicher und Warer Bericht vom Feldmessen, desgleichen vom Markscheiden*, Dr. Erasmus Reinhold, Erffurdt, 1574.

the indisputably consummate chapter in *De Re Metallica* had appeared eighteen years previously; but it is descriptive rather than educative, and the instruments are extremely primitive.

The figure of the 12 inches quadrant, reproduced here, shows also the *zeiger* (index) or alidade, with the usual sights, used

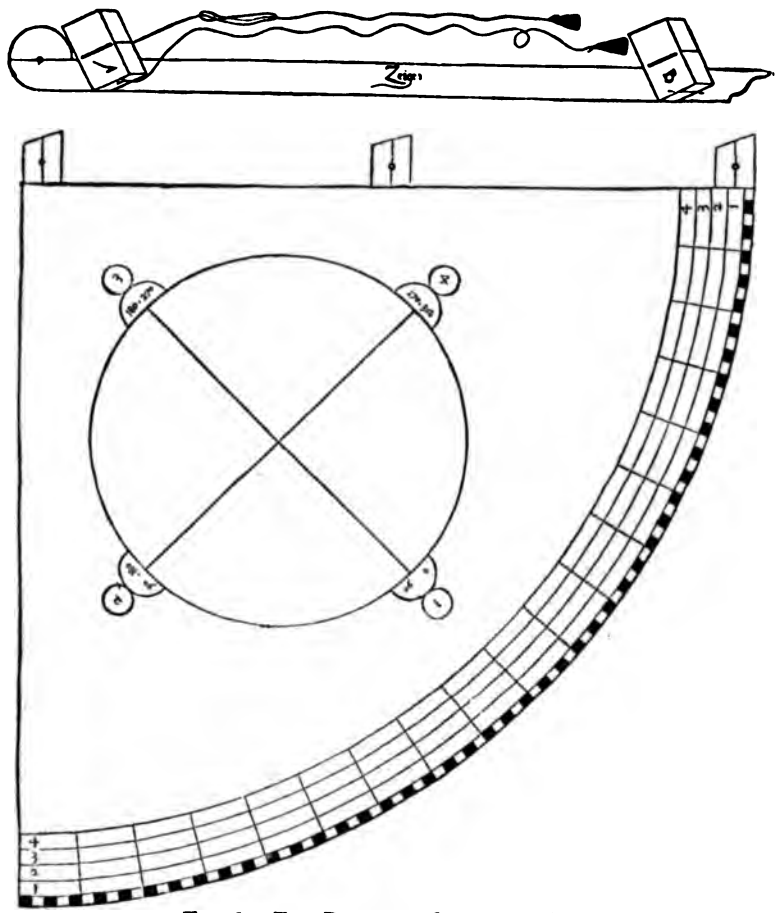


FIG. 1.—THE REINHOLD QUADRANT, 1574.

principally for the observation of horizontal angles. For taking inclinations, the quadrant was suspended occasionally from a cord, stretched from one station to another, at which times the small plummet was applied as in the *gradbogen* then, and to-day in connection with the hanging-compass system of surveying. (Fig. 9).

The quadrant, as well as the graduated semicircle, or gradbogen (between which there is no essential difference), was used for levelling and for the determination of heights and depths by the system of vertical angles, now known as hypsometry. This method of measuring the depths of inaccessible shallow shafts, pits, or wells, is very old. Apian describes it in his work* with an illustration (Fig. 2), that fully explains itself. The actual width of the bottom was first ascertained by dropping plumb-lines from a stick laid across the top. In the example which the author had selected, he finds the depth to be 166¾ ells to the surface of the water, but says he cannot attempt to measure the depth of the water in this way. One could hardly surmise the office of the holy man who is present, and possibly some would agree with the writer that, in the process of orientation by a difficult shaft-survey nowadays, a saint would be quite out of place.

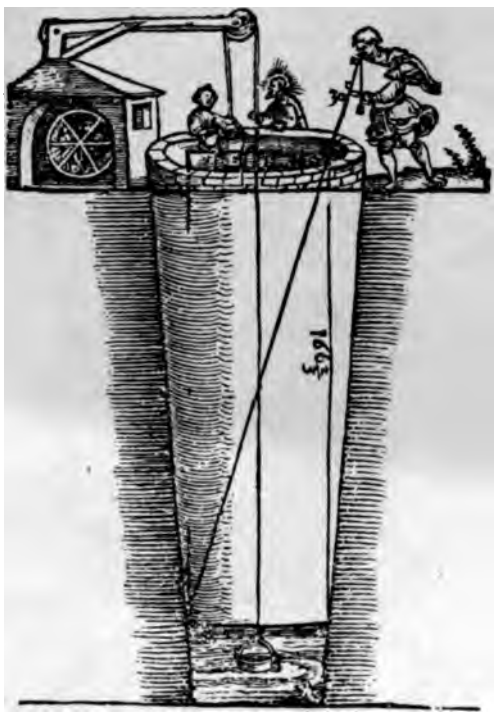


FIG. 2—THE APIAN QUADRANT, 1533.

*Setz - compass.* — Doubtless, following th quadrant, or some for of the astrolabe, the setz-compass appeared. This is, fund mentally, a magnetic needle with some kind of a graduated cir besides its own. The oldest instrument of this class, known exist, is the one to which Mr. Hoskold has referred,† as dat back to 1541. This date coincides so closely with the oldest served *Berg-privilegium*, which provided for the coinage of si taken from the Harz mines (1538 according to Beckmann), th is quite probable that the old setz-compass also came from

* *Instrument-Buch, durch Petrum Apianum*, Ingoldstadt, 1533.

† *Trans. Inst. M.E.*, 1900, vol. xix., page 180.

Harz.* It is 6·50 inches (165 millimetres) in diameter, the needle being 2·09 inches (53 millimetres) long, and about the outer circumference, the divisions, into twice twelve hours, are marked by small brass pins.†

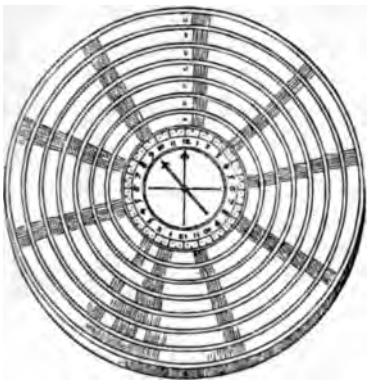


FIG. 3.—SETZ-COMPASS FROM AGRICOLA, 1556.

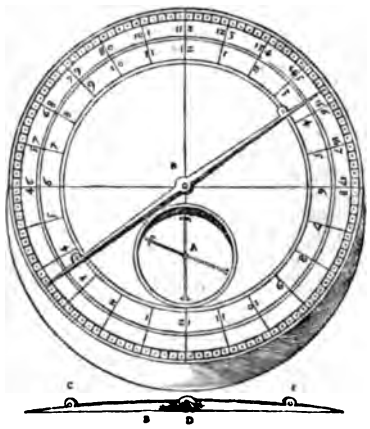


FIG. 4.—SETZ-COMPASS FROM AGRICOLA, 1556.

The oldest literature on the setz-compass is contained in chapter 5 of the oft-quoted *De Re Metallica*, by Agricola (Latin edition of 1556) unless we could truthfully say that the instrument spoken of in the anonymous work of 1505 came under this head. Both forms as they occur in *De Re Metallica* are shewn in Figs. 3 and 4 with the nadir-apparatus (Fig. 5) which was employed, in a rectangular wooden frame, for the purpose of levelling the compasses. Fig. 3 is that described by Mr. Hoskold ‡ In its use, a fine cord was drawn to the back and forward stations and a mark, indicating its direction, impressed into one of the seven variously coloured, wax-filled grooves. In the improved form, shown in Fig. 4, the cord was passed through the eyelets of the alidade and the indicated hour and minute recorded

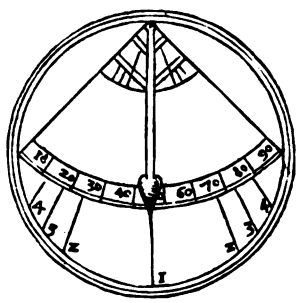


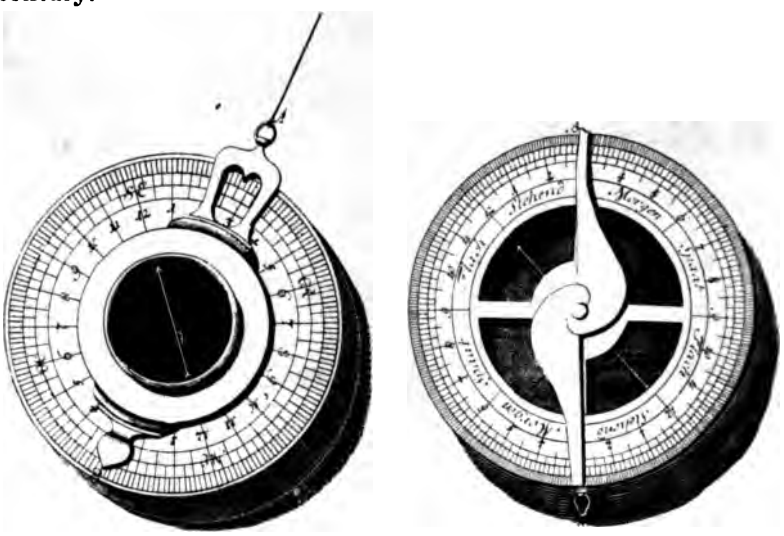
FIG. 5.—NADIR APPARATUS.

* *Berg- und Hüttenmaennische Zeitung*, 1879, vol. xxxviii., page 231.

† This simple little instrument seems to have been in use down to comparatively recent times. In *Abbildungen aller Berg- und Hütten-Beamten*, by Chr. Weigel, Nürnberg, 1788, is depicted, in a beautifully-coloured engraving, a uniformed surveyor with such an instrument mounted upon a simple staff.

‡ *Trans. Inst. M.E.*, 1900, vol. xix., page 179.

The forms of Voigtel* and Weidler† do not show sufficient improvement to warrant reproduction here. In each, the magnetic needle is mounted at the centre and the circular cavity surrounded by a movable flat ring, of which the index-arms are a part. The one described by Beyer (1749) is almost identical in appearance with Voigtel's; and those of Von Oppel‡ are worthy of special recognition, showing, as they do, a better form of construction, though hooks had been placed at the outer extremity of the index probably as early as the beginning of the seventeenth century.



FIGS. 6 and 7.—SETZ-COMPASSES, AFTER VON OPPEL, 1749.

Such instruments as those shown in Figs. 6 and 7 were adapted for use where the cord had to be drawn up or down on an inclined course, or draught, though not with entire satisfaction.

*Hanging-compass.*—Difficulties of this kind, in general, led to the introduction of the hanging-compass, usually attributed to Balthazar Rössler, in 1633 (though the writer had not yet discovered any such claim in his work); and the fallibility of the magnetic needle in particular, to a renewal of the ancient

* *Geometria Subterranea*, by Nicholas Voigtel, Eisleben, 1686-1713.

† *Institutiones Geometriæ Subterraneæ*, by J. F. Weidler, Wittenberg, 1726, Vienna, 1765.

‡ *Anleitung zur Markscheidekunst*, by F. W. von Oppel, Dresden, 1749.

mechanical methods by the introduction of the *eisenscheibe*. Concerning the hanging-compass, which, like the common British dial, is yet considered by many to be "pre-eminent among surveying instruments"* the writer would say but little, as the subject is too extensive and the opinions too varied to be recited in a short paper. Fig. 8, taken from Prof. Lempe's work,† except for its elaborate design, fairly represents the original model. Röss-

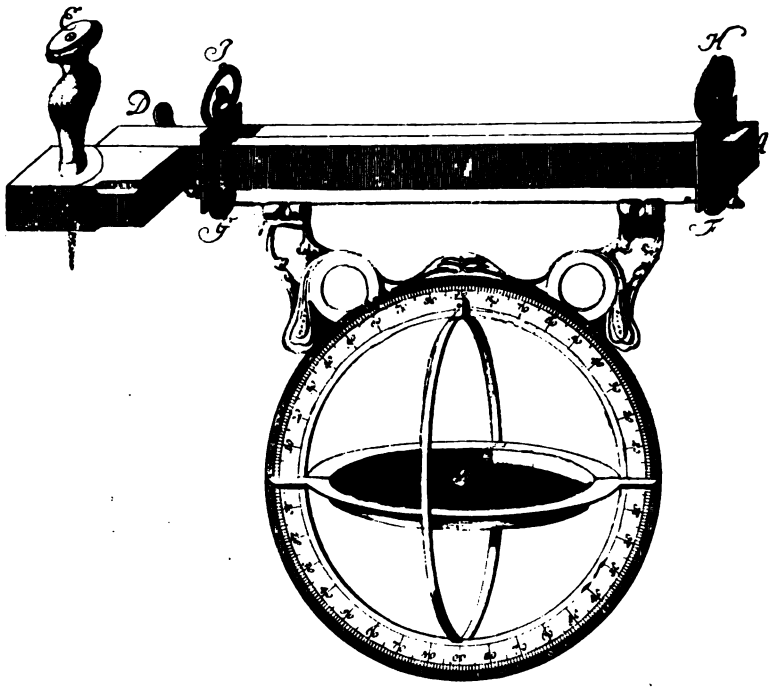



FIG. 8.—STATION POINTER AND HANGING COMPASS, MIDDLE OF THE EIGHTEENTH CENTURY, AFTER PROF. LEMPE.

ler‡ states that "those who resort to the old method of reproducing the survey on the surface have to encounter such obstacles as precipitous mountains, buildings, trees, rivers and the cold weather of winter." But the influences of the wind were overcome by the *winkelweiser* (for which we have no equivalent appellation in English) from which the compass may be seen suspended in Fig.

* *Trans. Inst. M.E.*, 1901, vol. xxi., page 20; and *Transactions of the American Institute of Mining Engineers*, vol. xxix., page 993, etc.

† *Gründliche Anleitung zur Markscheidekunst*, by J. F. Lempe, Leipzig, 1782-85.

‡ *Speculum Metallurgiæ Politissimum*, book iv., Dresden, 1700.

8. In ordinary underground work, a cord is stretched from one station-buck to another, and the compass hung from that position on the catenary curve that will give the nearest approach to the true vertical angle. In the employment of the *winkelweiser* the awl, E, is screwed firmly into the station-buck and the sights taken through I and H. If the sight were inclined, the instrument was tipped about the set-screw, D, and the vertical angle read upon the graduated circle. The exactness of this method, however, depended largely upon the possibility of the compass-box assuming a perfectly horizontal position in its gimbals, which, as will be evident, was a physical impossibility, because its centre of gravity was too nearly coincident with the line joining the points of support. In this particular it was not to be compared to the

FIG. 9.—THE GRADBOGEN AND AUSTRIAN BUCK.

*gradbogen*, whose first claim to accuracy is founded upon the unerring verticality of a freely suspended plumb-line. Fig. 9 is taken from Beer's work* and represents a surveying party using the Austrian buck in reproducing a survey of this kind on the surface. The author supposed that Budge was one of the influential surveyors, who, in England, stamped out the antiquated and absurd practice of attempting to repeat on the surface, the survey as made underground. It is amusing to read, in the last edition of his work (1866), how at Gwennap, the owner of a mine, weary of the various findings of several compass-surveyors, decided upon sinking a shaft where the pegs seemed to stand thickest.

In the second edition of Lempe's work (1785) is first described the now common form of hanging-compass, said to have been

* *Lehrbuch der Markscheidekunst*, by A. H. Beer, Prague, 1856, page 91.

designed by Schubert of Freiberg,* even though many modifications have since been devised, with a view of overcoming some of the difficulties attending its use. The principal of these, variation and local attraction, had received sufficient attention to occupy volumes in recording it, but the time, the place and incentive were not sufficient for the writer to enter into a discourse upon any part of it. Two of the extreme views will suffice. Mr. W. Lintern, in his work,† makes the astonishing statement that "the use of the needle affords the most correct results than can be attained in mining surveys," while Mr. Hecht,‡ on the contrary, says that where there is a suspicion of granite, porphyry, greenstone, serpentine, some kinds of tin, cobalt or nickel-ores, and of course in ironstone-mines, magnetite, or in slates where magnetic particles are embedded, it is quite unreliable.

*Circumferenter.*—Some of these facts have been recognized in Germany, France, Sweden and elsewhere, since mining became a legitimate industry and there had probably been no time in the history of magnetic surveying when the compass, on occasions, had not been superseded by the *eisenscheibe* (German), *graphomètre souterrain* (French), or *circumferenter* (English).

With the precise origin of this class of instruments, the writer was unfamiliar. He would, beyond doubt, be justified in tracing a transition directly from the astrolabe; and in such a case that would take us back to Hipparchus (160-125 B.C.) and the succeeding ages, of which, unfortunately, there was no adequate literature.

Strictly speaking, the Digges *theodelitus*, 1571,‖ is but an astrolabe, and as applied to mine-surveying would come under this classification. In his *Pantometria*, at the end of chapter 27, on "Longimetra," Digges speaks very briefly of mines, but very distinctly states that "You may make by the former precepts most certeine plattes of your ironies and thereby alwayse knowe under what place you are and which way to direct your Myne to approche any other place ye liste."

* *Lehrbuch der Praktischen Markscheidekunst*, by O. Brathuhn, Leipzig, 1884, page 38.

† *Mineral Surveyor and Valuer's Complete Guide*, by Mr. William Lintern, London, second edition, 1887.

‡ *Lehrbuch der Markscheidekunst*, by D. F. Hecht, Freyburg, 1829, page 69.

‖ *Trans. Inst. M.E.*, 1900, vol. xix., page 182.

Fig. 10 is taken from the work* that antedates Digges' *Pantometria* by twenty-one years and represents a man taking horizontal angles with an astrolabe, which had diopters (not shown in the illustration) upon the alidade, and is described as being a circle divided into four quadrants of 90 degrees each. In fact, its appearance in detail is almost identical with the Digges theodelitus, yet there seems to be nothing in the Latin text that would claim anything specially new in the design.

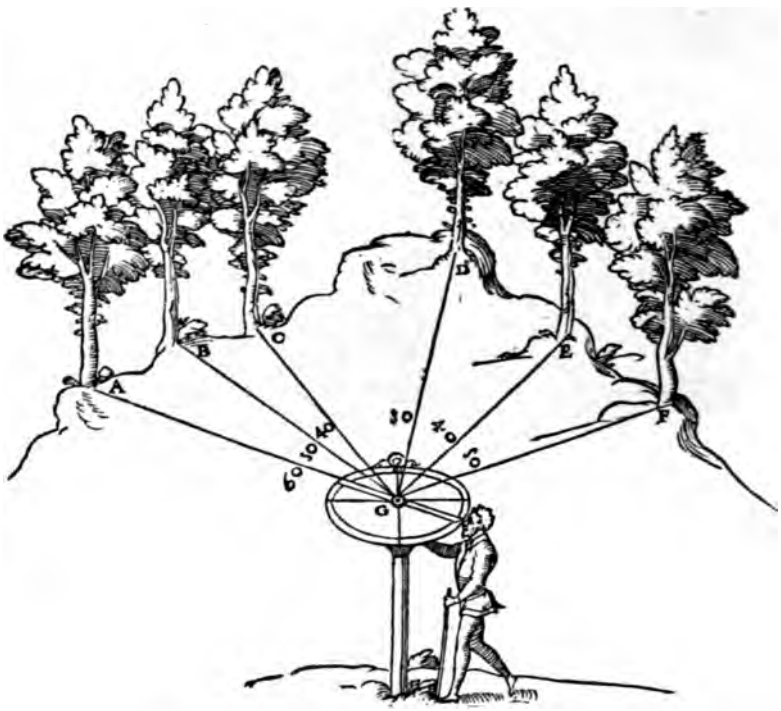



FIG. 10.—PLANISPHERE FROM ROJAS, 1550.

The English, with pardonable pride, point to the Digges theodelitus as the origin of the theodolite of to-day; but it does not seem unjust to say that from Digges we have the origin of the theodolite in name only, unless we consider the English cradle-theodolite which certainly had its beginning in the Digges "Topographicall Instrument," which he would touch upon later.

* *Commentariorum in Astrolabium*, by D. Johannis Rojas, Paris, 1550.

Voigtel's *eisenscheibe* (iron-disc) is reproduced in Fig. 11, as it occurs in the first edition of his work,* which bears the distinction of being the first exclusive treatise on mine-surveying ever published. It had a disc graduated into hours, as was common in compasses at that time, and was mounted upon a flat bar which could be screwed firmly to any improvised station, such as a plank wedged across a drift or tunnel. Invariably two, and preferably three, of these discs were used, and the zero of the advance-disc was always brought, by the set-screws, to coincide with the tightly-drawn cord, leading from the back-station to the hole at the centre of the instrument. Voigtel used the compass only to

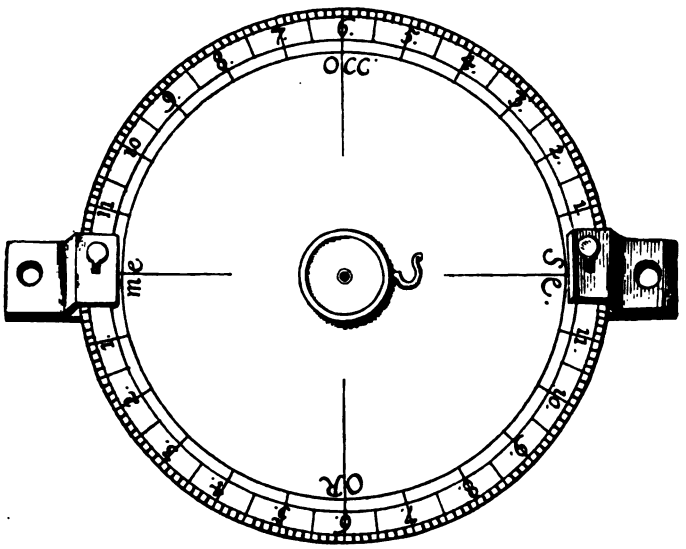



FIG. 11.—THE VOIGTEL EISENSCHEIBE, 1686.

determine the corrected magnetic bearing of the first course, thus anticipating the "fast-needle" method of Thomas Fenwick, and still it is more than probable that this was a common practice for many years prior to Voigtel's time.

How superior were these instruments to the compasses of the day, and yet how crude! It seems an inadequate dispensation of justice when we think of the fines imposed upon the commissioned surveyors, by the Government of Saxony, for any mistakes committed by their use.†

* *Geometria Subterranea*, by Nicholas Voigtel, Eisleben, 1686-1713.

† *Berg-Ordnung am Zellerfeldt*, Clausthal, 1689.

In the second edition of Fenwick's work,* he states that "since the conducting of subterraneous surveys requires now more attention . . . I am induced to suggest to the surveyor of mines a method, in which the magnetic needle has no control, excepting in the first departure." The instrument that he recommended for the pursuit of this method was the improved circumferenter of Jones (of London) the vernier-arm of which was fixed and the graduated circle, movable. Fig. 12 shows the arm, G, which was clamped from beneath at the centre.

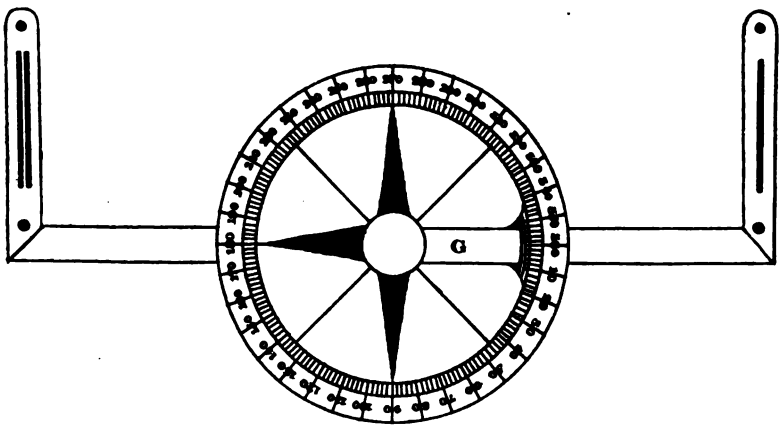



FIG. 12.—THE JONES-FENWICK CIRCUMFERENTER OF 1822.

Mr. Hoskold says that Budge continued to recommend the use of the miners' dial, and we must infer that he means the one we have just noticed, for, like Fenwick, Budge was a very practical and progressive man.

At page xii. of the introduction to his work,† Budge states that "It is a common practice in mining to take the angle of the underlying shafts with the cover of the dial and a plumb-line . . . but whenever any very important work is to be performed we would strongly recommend the application of more perfect instruments. . . . There doubtless are instruments much better adapted to the work both for speed and accuracy than the dial; and it is a matter of surprise that they have not been more generally introduced in our mines; of these instruments, the

* *A Treatise on Subterraneous Surveying*, by Thomas Fenwick, Durham, 1822, page 214. (The first edition was published in 1804.)

† *The Practical Miner's Guide*, by J. Budge, London and Devonport, 1825, 1845, and 1866.

theodolite certainly stands unrivalled for taking both horizontal and vertical angles." It is difficult to say, whether or not, Budge ever used a theodolite in mines, but this is, at least, one of the first appeals for higher efficiency in mine-surveying by the use of telescopic instruments.

Weidler's *eisenscheibe* and methods were not unlike those of Voigtel, but Maler introduces with his *stundenscheibe** (hour-circle) a novel feature shown in Fig. 13. The 12 inches graduated plate revolved upon another, as shown in the third figure of the diagram. A piece of it overlapped the lower plate, so that by an inserted thumb-screw, it could be clamped to any position as

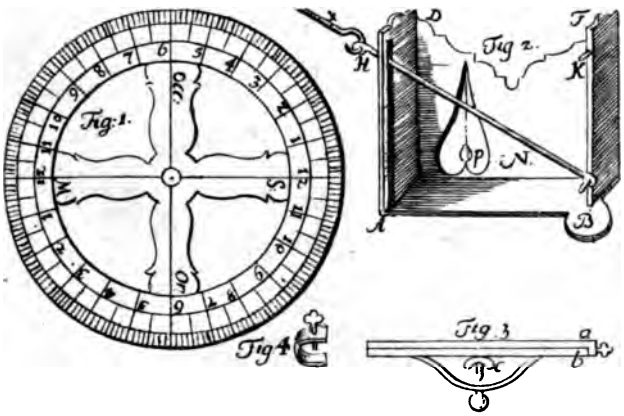



FIG. 13.—THE MALER STUNDENSCHEIBE, 1762.

desired. To secure additional permanency of adjustment, a separate clamp was used on the opposite side. The whole was mounted upon a tripod, a gang-plank or upon a single leg, as in Fig. 10, but in any case it had to be made very steady; for the tension of the cord, calculated to secure the best results, had a tendency to tip the instrument. Ordinarily, in the earlier models, if the cord had to be drawn above, or below, the horizontal plane, the indicated reading could not be taken with precision, even with the hooked index, so that the box-alidade was introduced. This device was pivoted at the centre of the plate by a screw at B, and the edge, A B, used to indicate the hour or angle, as might be, of the direction in which the cord was drawn. If an angle of

* *Geometrie und Markscheidekunst*, by J. F. Maler, Karlsruhe, 1762 and 1767, page 212; also *Geometria Forensis*, by C. L. Reinhold, Münster, 1781, vol. i., page 251.

declivity was to be dealt with, the inner extremity of the hooked bar was moved to the pivot, K.

Passing over the works and methods of Böhm (1718), Jugel (1744), Stigler (1767), Eberhardt (1773), Cancrinus (1773-1791), Kastner (1775), Gansanne (1776), du Hammel (1787), Kœnig (1780), Möhling (1793), Giuliani (1798), Komarzewski (1801) and von Voith (1805), we stop to consider a type of unusual interest that is preserved in the museum of Nürnberg.

Judging from the chirography on the bottom and the ornate style of decorating the plate in red, white and black, von Bezold believed this instrument (Fig. 14), to date back to 1600.* The

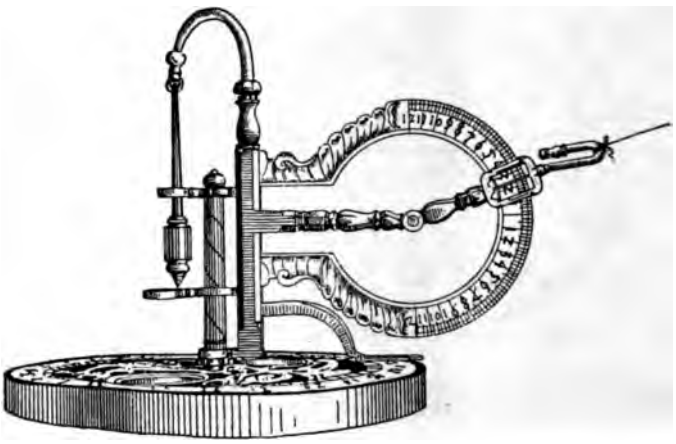


FIG. 14.—EISENSCHEIBE PRESERVED AT NÜRNBERG.

horizontal plate is made of pear-tree wood and is 6·93 inches (176 millimetres) in diameter. Both circles are divided into hours, and each hour into eight equal parts of 7½ minutes each. Two small magnetic needles are set into circular cavities at each end of the meridian-line. The peculiar pendulum-plumb was intended for levelling the instrument. The vertical arc extended outward from its axis in order that, not the line, but the cord of sight, so to speak, might range anywhere from the nadir to the zenith.

The only rational substitute for this eccentric feature was the model which appears in Fig. 15. This may be regarded as the

* *Wissenschaftliche Instrumente im Germanischen Museum*, by G. von Bezold, Nürnberg, 1897, page 41.

most modern type, although it originated as long as a century ago with Studer.* The figure represents the instrument as described in the works of Schneitler,† who advises, as usual, the use of three sets of bases, as shown in section at the left of the figure. The circles being at the intermediate station, revolved upon a spindle in the cartridge, *m*. A specially-designed brass pin, also shown in the illustration, takes the place of the upper part of the instrument at the forward- and back-stations. It is screwed into the socket, *m*, and so provided at the upper end with a hook or ring, that in drawing the cord, for instance, to the back station, it may be attached at the same point at which the arm of the vertical arc revolved when the instrument was mounted upon the back base. An ordinary bubble-tube was used to level the plates.

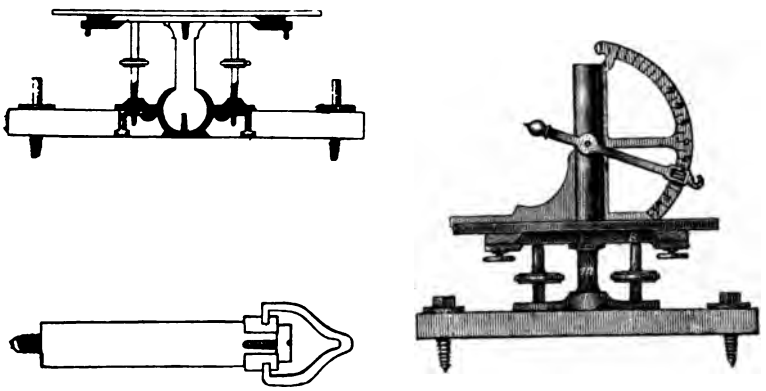


FIG. 15.—MODERN EISENSCHEIBE, AFTER STUDER, 1801.

In these later designs, the circles were divided by the sexagesimal system, and the alidades of both circles provided with verniers. This, we may say, was carrying the refinements too far; even though it must be acknowledged that, considering the simplicity of the apparatus, the system was exceptionally accurate.

It was, however, subject to certain apparent causes of error and by the middle of the past century, it began to give way, more and more, to the introduction of the high-class mine theodolite or transit, of which, he understood, it was the immediate forerunner.

* "Über Eisenscheiben," by J. G. Studer, in *Moll's Annalen*, Freiberg, 1802, vol. ii., page 387.

† *Instrumente und Werkzeuge der Höheren und Niederen Messkunst*, by C. F. Schneitler, Leipzig, 1848, pages 108 and 109.

*The Interchangeable Tripod and Target System.*—This system, as suggested in England by Butler Williams, in 1842, was doubtless acquired from Combes and d'Aubuisson, whom he quotes. The idea grew out of this method of using two or three *eisenscheiben*, but the first case of its application, to the best of the author's knowledge, was in connection with the pioneer mine-theodolite which Breithaupt introduced in 1798. Fig. 16 is only slightly smaller than the one in his work,* but it indicates the principle involved and indeed gives a fair idea of what the simple theodolite was like. The tripods at the forward- and back-stations carried signal-lamps which could be exchanged with the instrument by the triangular sockets provided in the telescopic tripods.

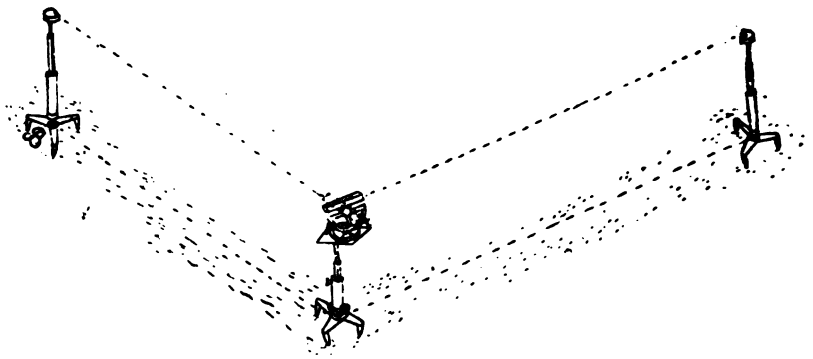


FIG. 16.—THE BREITHAUPT MINE THEODOLITE, WITH INTERCHANGEABLE TRIPODS AND SIGNALS, 1798.

This system, much improved, is used to some extent in Germany, in the coal-mines of Pennsylvania, and elsewhere to-day, but American engineers, generally, do not care for it. The writer believes that this is because, while rapid, the additional expense of the outfit is considerable and the essential advantage of the system leaves no permanent points for future reference. What may be said in its favour, will be found in the chapter on mine-surveying contained in Prof. W. G. Raymond's† book on *Plane Surveying*.‡ Generally speaking, it has no economic merit, and if the English engineer has disregarded Butler Williams' recommendations, he has exhibited good judgment.

* *Beschreibung eines Neu-Erfundenen Markscheider-Instruments*, by H. C. W Breithaupt, Kassel, 1800.

† Professor of civil engineering at the Renssellaer Polytechnic Institute, Troy, New York.

‡ New York, 1896.

The signal-tripods with candle-sockets, however, have been used in Cornwall since 1858,* and have been described in the Cantor Lectures on Mine-surveying† by Mr. Bennett H. Brough, who will possibly take exceptions to the opinion which the present writer has ventured to assert.

*The Cradle-theodolite.*—This theodolite, beyond any question, had its origin in the Digges "Topographicall Instrument" described in chapter 29 of his work *Pantometria*. The interesting picture of it presented in Fig. 17, will show it to be, as he

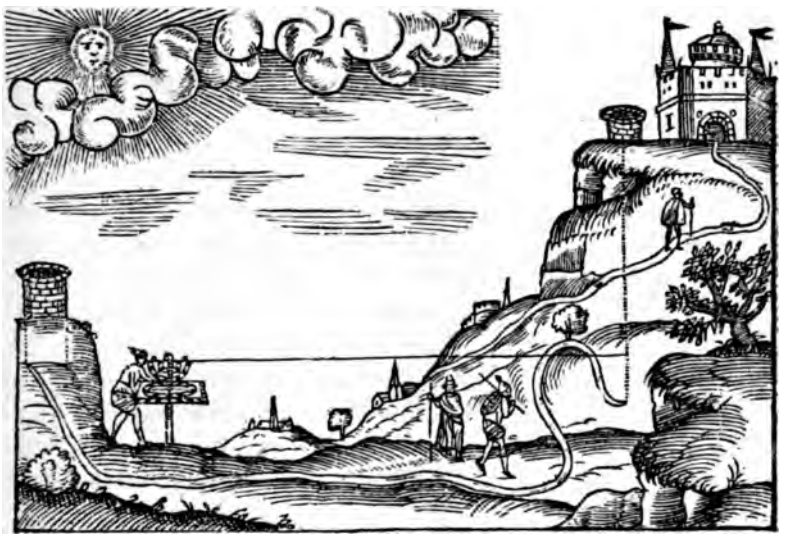


FIG. 17.—THE DIGGES TOPOGRAPHICAL INSTRUMENT, 1570.

claimed, a combination of the quadrant, the geometrical square and theodelitus; and altogether the most universal instrument of the time. In the figure, he undertook to determine how deep a well must be sunk from the castle, in order to intercept the water-course from a distant fountain or spring, but "no mãner of altitude, latitude, longitude, or profunditie can offer itself, howsoever it be situate, which you may not both readily and most exactly measure." Then he continues "It is also requisite that

* *Evolution of the Mine-theodolite*, by Mr. E. W. Newton, Camborne, 1894.

† *Journal of the Society for the Encouragement of Arts, Manufactures and Commerce*, London, 1892, vol. xl., page 812.

within theodelitus* you have a needle or fly so rectified, that being brought to his due place, the cross diameters of the planisphere may demonstrate the foure principall quarters of the Horizon. . . . And this may you do by drawing a right line making an angle (with that one diameter of youre instrument representing the meridiane) equal to the variation of the cõpasse in youre region: which in England is 11¼ grades, or neere therabout, and redely observed in all places sundrie wayes."

There is sufficient evidence in the preface of the above-mentioned work to show that Leonard Digges actually had in use, possibly as early as 1565, a reflecting telescope, but it is quite probable that telescopes were not used in connection with this type of instrument until Jonathan Sisson, a celebrated London optician, introduced his improved theodolite in or about 1723.

In the last or fifth edition of Leybourne's *Surveying* (1722) which must be regarded as an authority for that time, there is nothing mentioned in reference to an improvement of this kind. He records the simple fact that the geometrical square had been generally discarded in the Digges instrument, and that the plane-table with degrees marked around the outer edge (a practice which began in England in 1674) was considered the most perfect type of any then known.

Henry Wilson, in his *Improved Surveying*,† seems to denounce contemporaneous (probably Laurence's and Gardner's) works as being a transcription of Cunn's appendix to Leybourne, but although he may have had a knowledge of it, he does not mention the telescopic theodolite.

At any rate, this improvement had not reached Scotland by

* The manner in which Digges uses this word without the definite article has led some etymologists to conjecture its derivation from a corruption of "the alidade," but this is improbable, as he speaks distinctly of the *Alhidada* as in its commonly accepted meaning. Figuring, however, on this method, the original derivative must have been the *Odelitus* or *Ododitus*, which the late Prof. Adams has designated as the periphery of a circle marked, or scratched, by divisional lines. Prof. W. W. Skeat in *Notes and Queries*, 1895, vol. viii., page 130, considers this somewhat fanciful, first indicating a desire to attribute its origin to Theodulus, if such a man were known to be associated with mathematical instruments. We know that Cicero speaks of Archimedes as the inventor of the sphere (*globus*) and that later Theodosius of Bithynia wrote a commentary upon it. According to the old French custom, this work, on the science of circles, would have been known as *Theodosie*, whereas Godefroy in his old French Dictionary gives reference only to the work called *Theodulet*, without explanation. The most authoritative work, to date, that can be consulted on the derivation of this obscure word is Prof. Skeat's *Concise Etymological Dictionary*, Oxford, 1901.

† *Improved Surveying*, second edition, London, 1731.

1757, for in that year, John Gray of Glasgow, describes in his *Art of Land-measuring* only the wooden or brass graphometer.

Apart from the expense of even the smaller telescopes, the writer supposed that some of the physical defects in their manufacture precluded their use on portable instruments. The simple refracting telescope was a very imperfect instrument, owing to its chromatic aberration, which was not generally overcome until Dollond published the construction of his aplanatic objectives in 1758. By greatly increasing the distance between the objective and ocular, in proportion to their diameters, a part of this difficulty had been rectified. In 1659, Huyghens and Cassini had in use a telescope 100 feet long ; and others of this class, which came to be known as "aerial telescopes," on account of there being no tube-connection, attained the extraordinary length of 212 feet. Bradley had such an one in use in 1722, for making observations upon the planet Venus.

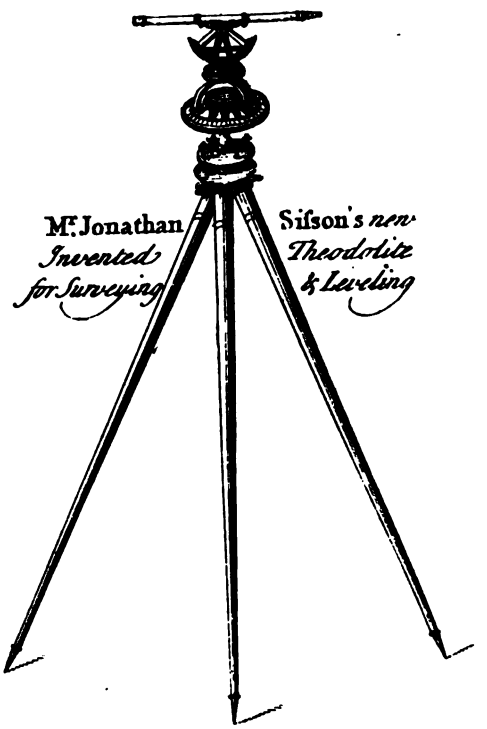



FIG. 18.—THE SISSON THEODOLITE OF 1723.

Although Laurence* says nothing of this inherent defect, the writer thought that there was an effort on the part of Sisson to overcome chromatic aberration, to some extent, by using a telescope of disproportionate length, as will appear in Fig. 18. A short description may be given of this remarkable old instrument in Laurence's own words.

> The Ball and Socket of this Instrument are so contrived, that by the help of four screws placed at Right Angles to one another, below the Center, the whole is very readily fix'd *horizontal* as well as *steady;* and thereby not liable to any Motion or Variation upon moving the *Index*. There is a double *sextant* of

* *Duty and Office of a Land Steward*, by Edw. Laurence, London, 1723 and 1731.

Equal Radius to the Limb (with a *Spirit-Level* fix'd in it, and a *Telescope* above it) that moves in a Circle at Right Angles to the *Index* on the Limb; whereby the *vertical* Angles may be taken readily as the *horizontal*, and at the same time; and so the *hypotenusal* Lines may be reduced to *horizontal*, which are those that should always be laid down in *plotting* any Survey.

The Head of the three-legg'd Staff is of Brass, and not so liable to *shake* as the wooden ones: The Needle in the *Compass-box* hangs on a Pin of temper'd Steel (turn'd and polish'd in a Lath) on which it moves very freely; and the Limb is so curiously divided, (by a new Method) that tho' there be three *Indexes* at 120° from each other, with *Nonius's* Divisions on them, to show the decimal Parts of a Degree; yet you shall perceive no Inequality in the Divisions on any part of the whole Circle. There is also a Spring and Screw to the *Index* under the *Telescope* to fix it to any Degree of the Limb. The whole is nicely framed, very portable, and well contrived for dispatch of Business.

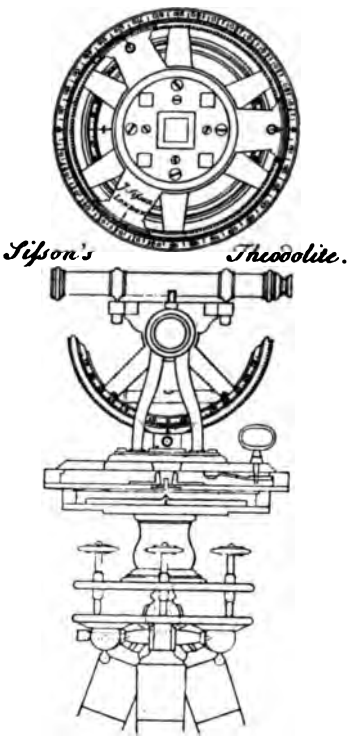



FIG. 19.—THE SISSON THEODOLITE OF 1737.

The next time that we hear of the Sisson theodolite, as pointed out by Mr. W. F. Stanley,* who, by the way, was first to start anything like a connected history concerning these instruments, is in Gardner's work,† where it appears much improved, as shown in Fig. 19. The telescope is considerably shortened, indeed, "a little shorter than the diameter of the Limb, that a fall may not hurt it; yet it will magnify as much, and show a distant object as perfect as most of treble its length." All the details of its construction seem to have been worked out with great care, even to inculcate the general ideas upon which all subsequent models have been fashioned. It was sheer speculation on the writer's part, but the circumstantial evidence seemed sufficient to conclude that Sisson caught the secret from Chester Moor Hall, of whom he had already spoken, and actually introduced this instrument in 1737 with a practically achromatic telescope, twenty-one years

* *Surveying Instruments*, by Mr. William Ford Stanley, London, 1890, 1895, and 1901, page 3.

† *Practical Surveying*, by Wm. Gardner, London, 1737, page 59.

before Dollond gave the results of his experiments to the world. The limb of this instrument was "curiously divided into whole degrees and numbered to the left hand, at every 10, to twice 180, having three indexes, distant 120 (with Nonius's divisions on each for the decimals of a degree), that are moved by a pinion fixt below one of them, without moving the Limb, and in another is a screw and spring under, to fix it to any part of the Limb. The Double-Sextant is divided on one side to above 60 degrees each way and the double index (through which it is moveable) shows on the same side the degree and decimal of any altitude or depression to that extent by Nonius's (*sic*) divisions, and on the other side are divisions numbered for reducing hypothenusal lines to horizontal. The telescope has in its focus very fine cross-wires, whose intersection is in the plane of the Double-Sextant, and this was a whole Circle, and turn'd in a Lathe to a true Plane."

The rack-and-pinion manœuvring of the horizontal, as well as the vertical limb seems to have been common down to the closing years of the eighteenth century. In 1797, we find W. and S. Jones, in their revision of Adams' *Geometrical Essays* (1791), giving beautiful illustrations and careful descriptions of such instruments, as those, made by the celebrated Ramsden, to which he had added the verifying telescope beneath the horizontal plates. By this time, also, the bubble-tube had been attached to the telescope, instead of to the vertical arc, and two smaller ones had been fixed, as is common to-day, to the horizontal plates.

Cradle-theodolites with racked vertical arcs may be found described in the *Elements of Land-surveying* by A. Crocker (London, 1817, etc.), in G. D. Burr's *Practical Surveying* (London, 1839 and 1864), and in J. Gummere's *Treatise on Surveying* as first published in 1814 and as subsequently revised by Isaac Sharpless of Philadelphia as late as 1880, although the writer would not assert that the more progressive makers or practitioners, on either side of the Atlantic, had retained this imperfect device to anything like such recent times.

Perhaps it is saying too much for the ingenious Ramsden to credit him with having been the first to combine the altitude and azimuth circles in a single instrument. There is a popular opinion extant which ascribes the invention of the transit to Olaus Römer, the Danish astronomer in 1689,* and also that in 1704 he

* *Miscellanea Berolinensia*, 1700.

had combined with it a full vertical circle. Previously, the astronomical quadrant had been commonly employed for the determination of celestial altitudes. For this, in 1669, Picard substituted a telescope for the ordinary sights; and in 1689, John Flamsteed, the first Astronomer Royal and enemy of Newton, introduced spider-lines in its focal plane.

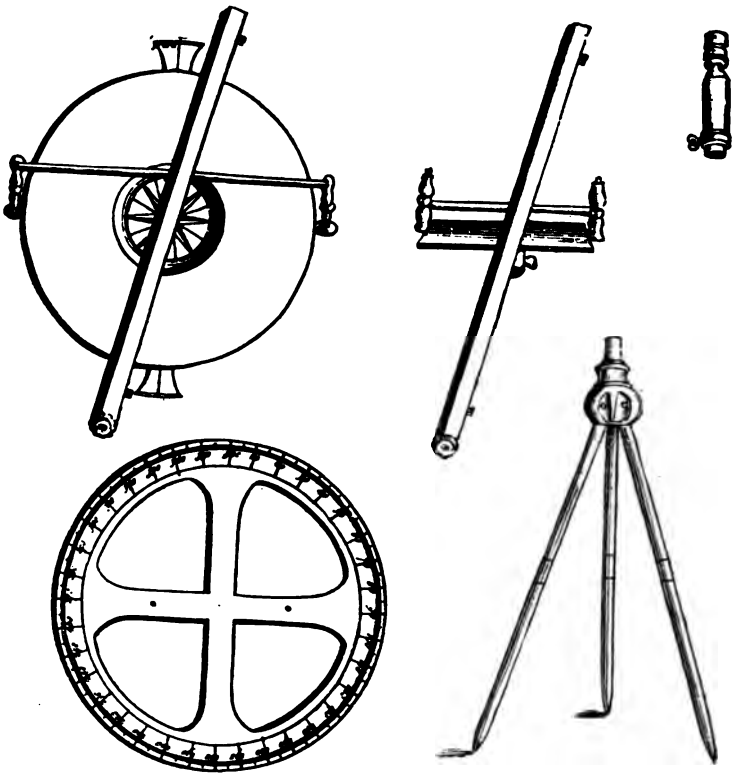


FIG. 20.—THE STONE THEODOLITE OF 1723.

In 1723, Edmund Stone stated that the most perfect theodolite then made in England* was one contrived after the French model and upon principles of construction similar to those which identify the repeating circles of Jean Charles Borda (1733-1799).† Fig. 20 will give an idea of the parts in their order, beginning at

* *The Construction and Principal Uses of Mathematical Instruments*, translated from the French of M. Bion (1713), by E. Stone, London, 1723, page 127.

† C. F. Schneitler gives an accurate description of Borda's multiplication-circles as improved by Troughton. The same may also be found in *Erd-, Land- und Feld-messung*, by W. E. A. von Schlieben, Leipzig, 1821, page 44.

he left. The graduated brass-circle is 12 to 14 inches in dia-
neter, divided into degrees, and these in turn are subdivided,
ptionally, by the diagonal scale or by the vernier system. Upon
his revolves a brass disc, shown above,with its indices cut to coin-
ide precisely with the graduations of the circle. In the centre
s a compass-box and above, on an axis between the short pillars,
ests a square-tube telescope the line of collimation of which was
djusted to be coincident with the line joining the indices.
Beneath the graduated plate, at the holes shown in it, were fixed
he short pillars, in such a careful manner that the lower square-
ube telescope, which was suspended between them, should always
oincide with the zero-line of the circle. This arrangement made
t convenient for use in taking back-sights. This part of the in-
trument was habitually set into a ball-and-socket joint, and this,
n turn, clamped to a tripod. By small internal screws, the legs of
he tripod could be shortened at the central joints for work in
ow places. In the illustrations, the telescopes are purposely
urned out of place in order to show more clearly the features
eneath.

The French model of this type differed only in that the centre-
pace of the graduated circle was filled with cardboard discs and
he square-tube telescope was mounted upon a central pivot and
rostrate upon them. By this means, not only was the numerical
alue of the angle observed, but a graphic record of it made, along
he edge of the telescope, on the cardboard.

Mr. Bennett H. Brough had spoken of Gen. James Douglas'
'Infallible Instrument," described by the inventor in 1727* as
eing a forerunner of that most approved Cornish instrument, the
Henderson rapid traverser,† but both, it appears, came from the
French.

The Swedes have been practising in their magnetic iron-
nines, for more than 150 years, a method similar to this, but more
trictly speaking, a modification of the plane-table system which
Mr. Nordenström described fully in 1897.‡

The most notable magnetic instruments used in Sweden are
the Thalèn magnetometer and the Tiberg inclination-balance,

* *Transactions of the American Institute of Mining Engineers*, 1900, vol. xix., page 993.

† *Trans. Inst. M.E.*, 1893, vol. v., page 199.

‡ *L'Industrie Minière de la Suède*, Stockholm, 1897.

which Mr. Bennett H. Brough had described in 1887.* Curiously, however, they are more frequently used for exploring for magnetite than for subterranean surveying.†

While this may be regarded as a possible exception, the rule has been, ever since mathematics has been allied with mining, that the advocates and opponents of the magnetic needle in all countries, have worked side by side with occasional disaster, which the writer believes has been due to causes instrumental on the one hand and personal on the other. If engineers were more cheerful about recording their mistakes, better comparisons could be drawn.

When one contemplates such instruments as the Gauss-Borchers magnetometer (1846) and the Breithaupt orientation-instrument (1887), one is impressed with the extent to which the Germans alone have gone to make magnetic surveying all that it should be; and yet the writer believes that its adherents were becoming less numerous with each generation. In European countries, there seems to be something almost sacred in the perpetuation of a time-honoured custom. Here at Houghton, in the Michigan School of Mines, the subject is dealt with only incidentally as being applicable to the most ordinary kinds of work.

The Breithaupt orientation-instrument is worth casual notice. The one shewn in Fig. 21 is the form, made by Ludwig Tesdorpf in 1897. Its most characteristic feature consists in the insertion of a trough-box compass through the base of the standards, in such a manner that the needle may be viewed through the telescope. This is accomplished by an additional objective-lens, by which the instrument is converted into a telengiscope. The needle is usually 8 inches (20 centimetres) long and delicately mounted upon a ruby. After it has been viewed, while resting quietly in the magnetic meridian, the additional objective-lens is removed and the azimuth of any course read on the plates. On the larger instruments, this may be determined to the nearest $\frac{1}{3}$ minute. The peculiar office of the additional lens has been proposed for use in viewing stations that may occur very near to the instrument (say with 5 feet); but, theoretically, this is impossible,

* *Journal of the Iron and Steel Institute*, 1887, vol. i., page 289.

† Excellent illustrations and a comprehensive description of this method may be consulted in Prof. P. Uhlich's *Lehrbuch der Markscheidekunde*, Freiberg, 1901, page 337.

is well known that after the line of collimation has been ted it is likely to be deranged by even loosening or in any way

FIG. 21.—ORIENTATION INSTRUMENT.

rbing the objective. As the instrument has only a special ion, it is usually not provided with a vertical circle, though

it is quite possible to have it so constructed. In the Tesdorpf model, the maker has adroitly counterbalanced the illuminating lamp by a side auxiliary telescope, on the opposite side of the horizontal axis, by which means the orientation may be carried directly down a very precipitous shaft.

*American Mine-compass.*—When we touch upon auxiliary telescopes, we are brought to the consideration of the feature that, more than any other, characterizes the American mine transit; but let us first investigate one or two of the later designs of American mine-compasses. The history of earlier mining in Pennsylvania has been associated with various types of both the English and German dial of foreign and domestic make, but latterly the use of the compass-instrument has been almost exclusively confined to the remote districts of the Rocky Mountains both in the United States and in Canada, where it would be difficult if not impossible, to take a heavier transit-instrument along with the necessaries of life.

One of the notable examples of this class is the "simple and convenient" instrument* of Mr. Frank Robbins.† It was originally made for him in 1888 by Mr. John Roach of San Francisco with a Goyjot joint (Fig. 22), which is quite universal in its action and with sufficient friction in the bearings to provide steadiness for so light an instrument. With the folding sights and the pendulum plumb, inside the compass-box, both horizontal and vertical observations could be made. After having taken a steep sight, however, it was a matter of some conjecture to bring the compass back to a correct horizontal position for the purpose of reading the magnetic bearings; so that sights, such as are shown in Fig. 22 were introduced. Mr. Robbins originally intended that the auxiliary sights should be made upon a slide that could be slipped over the principal sights as desired, but on his submitting the plans to Messrs. W. and L. E. Gurley in 1896, they simply hinged them as shown in the illustration. By the introduction of the auxiliary sights, the more ordinary ball-and-socket joint was employed. The size of the instrument is such that the compass may be carried in the pocket, and the legs of the standard folded back upon it into a bundle about 2 feet long.

* *Transactions of the Canadian Mining Institute*, 1900, vol. iv., page 99.

† Mining engineer, North Star mines, Nelson, British Columbia.

Mr. Robbins informed the author that in the great masses of rrhotite (magnetic pyrites, $Fe_7S_8$), which are to be encountered

FIG. 22.—THE ROBBINS DIAL, MADE BY MESSRS. GURLEY, SHOWING THE GOYJOT JOINT AS USED IN THE ORIGINAL MODEL.

the north-west of Canada, it is impossible to do anything like asonably close work except to set up at each station and intro-

duce every possible correction and precaution; but he states also that his dial is only intended for use as an expedient, and for such prospectors as he had seen making surveys with a 1½ inches compass and plotting it on wrapping paper with a carpenter's pencil and a 2 feet rule.

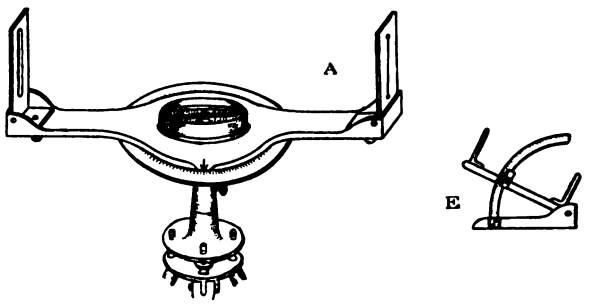



FIG. 23. – "FRYING-PAN" DIAL.

Mr. Robbins had sent the writer a description of a curious instrument which he found an old surveyor using in the mines of Nevada, U.S.A., between 1870 and 1880. A very rude sketch of it is presented in Fig. 23, and the writer had pleasure in submitting his account of it *verbatim*:—

It was one of the old frying-pan type. The upper plate, with compass and sights, traversed a lower plate which was graduated to ¼ degrees. As I remember it, there were no slow-motion or tangent-screws. The novelty consisted in the sights, which slid in guides in the extremities of the upper plate, being fixed by thumb-screws from beneath. Removing one of the sights, the clinometer, E, could be substituted for use in steep sighting. There was no vernier; merely an index at opposite sides on the upper plate. At these points, the plate was filed down to a thin edge.

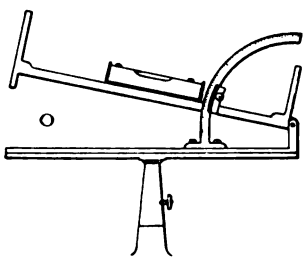



FIG. 24.—THE ROBBINS EXPEDIENT FOR SPINDLE-TRANSITS.

Fig. 24 shows an expedient of my own, though there is nothing startling in the originality of it. I had an apparently guileless old transit, the first that I ever owned, and before the day of shifting centres (1858). It was gracefully poised by means of a socket-and-pivot on the levelling-head. It had a vertical circle, but this of course did not admit of taking any very steep angles of elevation or depression, nor of establishing the alignment in similar slopes. I was fortunate, perhaps, in having the spindle and socket, for I could see an easy way out of the difficulty by having a socket brazed to an ordinary clinometer. Now, when I encountered a steep incline I merely took off the transit, substituted the clinometer,

xed the point above, or below, read the inclination, and then established an ıtermediate point somewhere within range of the telescope of the transit. The ansit then reassumed its position on the spindle, and the work progressed as efore.

Curiously enough all these models embrace a modification of he idea, which the Austrians and others had utilized for many ears in connection with the common form of alidade as used with he plane-table in mountainous countries. It is called by them the *ergdioptern*, and is reproduced in Fig. 25, from Mr. F. Hartner's ork,* where the importance of its careful adjustment is mphasized. It is obviously necessary that the hinges of the uxiliary sights should work, not only in harmony with each other, ut with the principal sights. It is well known that the Swedes ave used this device in a modified form peculiarly suited to their eeds, for over a hundred years.†

FIG. 25.—SIMPLE PLANE-TABLE ALIDADE FOR MOUNTAINOUS DISTRICTS.

One of the most notable pocket-instruments of this general lass is that of Mr. A. P. Blandy,‡ as made in 1901 by Messrs. . and R. Wittstock.‖ Fig. 26 shows the instrument in both orizontal and vertical positions, and is so very clear in all details hat little descriptive matter need be given. In either position, he 3½ inches reversion-bubble serves to level the instrument. he four 4 inches folding-sights, with the usual slits (overlooked n the cut), may be used to determine vertical angles, roughly, p to 40 degrees; though these are preferably observed to the earest minute on the edge-graduation of the 4 inches limb, when he instrument is tipped in the slot of the ball-and-socket joint.

* *Handbuch der Niedern Geodäsie*, by Fr. Hartner, first edition 1850, second dition 1856, page 93.

† *Reise durch Scandinavien in den Jahren* 1806 *und* 1807, by J. F. L. ausmann, Gottingen, 1811 and 1819, vol. i., page 115.

‡ Mining engineer, Silver-king mines, Nelson, British Columbia.

‖ Plan Ufer 92, Berlin, Germany.

The bar-needle is 3½ inches long, and its circle graduated to ½ degree. The pendulum is used principally as a clinometer in connection with the square extension of the base, when the instrument is removed from the tripod. The weight of the leather case, containing the instrument with mounting, and a plumb-bob, is 2·7 pounds, and the outside dimensions are 5¾ inches by 5¾ inches by 2 inches. The tripod weighs 1·8 pounds, it will extend to a height of 4¼ feet, and fold within a space of 15 inches by 2¼ inches by 1½ inches.

FIG. 26.—THE BLANDY DIAL, AFTER WITTSTOCK.

In 1894, Messrs. W. Ainsworth & Son, of Denver, Colorado, U.S.A., first made for Mr. D. W. Brunton of that city, a pocket hand-compass designed after the ideas which prevail in the *boussole topographique* of Colonel Hossard, as introduced into France nearly thirty years ago. It has won great popularity, on account of its extreme portability as well as the rapidity with which observations may be made. The hurried examination of

distant mines is facilitated by its use, as it is provided, within its diminutive dimensions, with the appliances calculated to replace the clinometer and hand-level. The principle of its operation is founded upon the coincidence of the vertical line in the mirror of the cover with the reflected image of the sight and the object sighted to. A glance at Fig. 27 will explain the use of the instrument. The dimensions are $2\frac{3}{4}$ inches by $2\frac{3}{4}$ inches by 1 inch, and the weight, in an aluminium-case, is only 8 ounces. Horizontal angles are determined by the needle, and vertical angles by the clinometer, as shown in the illustration. It is especially recommended for use in geological surveys.

FIG. 27.—THE BRUNTON. HAND-COMPASS.

*Brief Review of some American Mine-transits.*—About the first indigenous mine-transit that made its appearance in America was one designed (Fig. 28) by Mr. Edmund Draper, who became established in Philadelphia in 1832.* There is very little reliable information concerning it, but it is supposed to have been made about 1855; though the particular instrument shewn in Fig. 28, could not have been made prior to 1859 or 1860, as this style of shifting tripod-head was not brought out until that date. The pillars which supported the telescope were placed upon an extension of the vernier-plates. The metal between them was so cut away that the telescope could be directed at any object, no matter what the acclivity or declivity. The evident prime object

* The illustration is reproduced by the courtesy of Mr. Draper's successor, Mr. F. C. Knight, 402 Locust Street, Philadelphia, Pennsylvania.

in this pattern is to get the telescope revolving upon an axis far enough outside the plates to permit a vertical sight, and in this particular it belongs to the same class as those instruments in which the standards have been inclined forward. The same results are achieved in either case.

There was some doubt in the writer's mind as to which pattern appeared first. We know that Mr. Young* made a transit with inclined standards for Mr. Alexander Roberts of Hamburg, Pennsylvania, as far back as 1854, and if any were made between 1831 and that date we have no record of it. As the portable transit-instrument began in America, with Mr. Young, at the latter date, it is safe to assume that the inclined standards had not appeared at any time previously. At any rate, they were not much used until the late Mr. T. S. McNair, Hazleton, Pennsylvania, introduced them at the Lehigh mines in 1875.

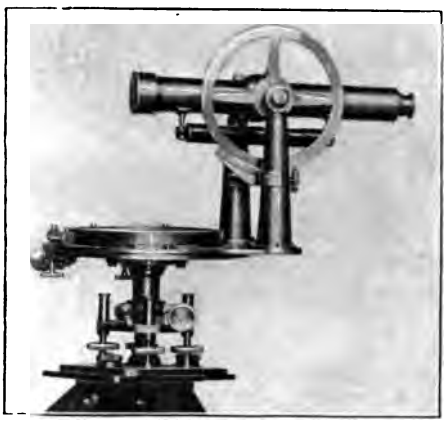


FIG. 28.—THE DRAPER MINE-TRANSIT, 1859.

One of the later models (Fig. 29), as made by Mr. Knight, is introduced, more for the purpose of bringing before the members the instrument which Mr. Hoskold characterizes as "awkward and unsightly," than in the hope of converting his British cousins to one of the accepted American methods. However, the writer would not say that Mr. Hoskold's opinion was entirely free from prejudice, for this type of instrument had been used in nearly every mining district from the Atlantic to the Pacific in the past quarter of a century, and indeed the efficiency of any instrument ought to be accepted as weightier evidence than that of its outward appearance.

Fig. 29 represents one of the standard models of the American eccentric mine-transit, and as we compare it with the German eccentric mine-theodolite, it will be found to possess one prominent point of superiority, namely:—Whenever an horizontal angle is

* Messrs. Young & Son, 43 North Seventh Street, Philadelphia, Pennsylvania.

observed, it may be read without correction. The vertical circle being concentric with the axis of the telescope, the indicated angle of elevation or depression will be correct for the position in which the telescope lies, but in attempting to reduce the observation to the centre of the instrument some complication is involved. To fulfil the rules to be observed in the best of instrumental construction, a counterpoise weight should be attached beneath the plates and opposite the side where the telescope is suspended.

FIG. 29.—AMERICAN ECCENTRIC MINE-TRANSIT.

*American Auxiliary Telescopes.*—The German and French eccentric mine-theodolite, the writer believes, is giving way to the concentric model, except for such special work as Borchers and Combes intended. These and the American eccentric-transit correspond in their operations to the work that is attainable in American auxiliary telescopes. The instrument with inclined standards will perform the work of the top auxiliary telescope, and do it, for obvious reasons, even more exactly, so that many engineers, with excellent arguments, use this instrument and humour its occasional shortcomings in preference to the concentric model with the usual form of the detachable top telescope.*

* Mr. Joseph Barrell in *Mines and Minerals* (Scranton, Pa.), 1899, vol. xix., page 433.

Top and side auxiliary telescopes have been used by American mining engineers since about 1855 or 1856, though the writer did not know that these were ever made or used habitually in France as Mr. Hoskold said, except perhaps in imitation of the American device. As a matter of fact, mine-theodolites or transits, with additional eccentric telescopes, are common in the United States, rare in Germany and in Cornwall, and rarer still in France and Belgium.

Prior to 1881, when Mr. G. N. Saegmuller* introduced his telescopic solar attachment, the auxiliary top telescope had been fixed to the main telescope by two short pillars with coupling nuts, but since that date engineers have begun to request a slightly

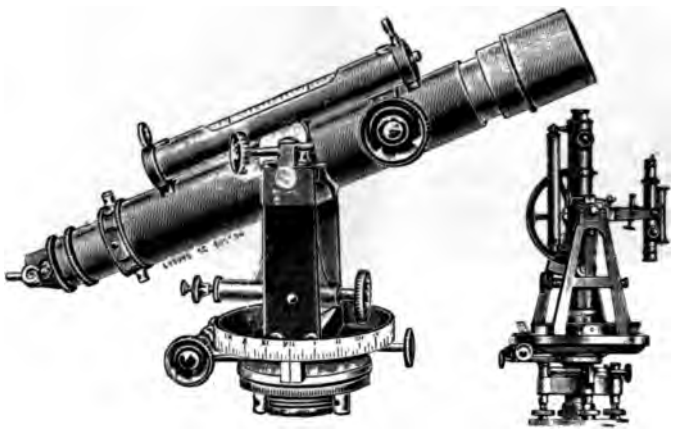


FIG. 30.—THE SAEGMULLER SOLAR ATTACHMENT AND LIGHT MOUNTAIN-TRANSIT.

larger model of about 18 diameters power to use for both the determination of the solar meridian and for steep or vertical sighting in shafts.

Fig. 30 shows the latest model† and a miniature illustration of a light, 4 inches, mountain-transit, to which it had been attached. The only special requirement in the instrument is a hub sufficiently large to receive a countersunk hole, into which the threaded base of the attachment may be screwed. This done, the attachment is adjusted to work in harmony with the instrument by the capstan-head screws, which operate between the small

* Trading as Fauth & Co., Washington, D.C.

† The original model and one of the first instruments to which it was attached may be found in *The Topographer*, by Mr. L. M. Haupt, New York, 1883, where the description and instructions are from the pen of the inventor.

parallel plates. If the vertical, or polar axis of the attachment be made to occupy a position perpendicular to the horizontal axis of the main telescope, both telescopes will revolve in the same vertical plane. All the means of adjustment necessary to obtain this relationship are supplied. The only possible objection to the device, for mining purposes, lies in the fact that the small telescope being capable of movement in altitude, care must be exercised to preserve parallelism in the collimation of the telescopes; and even under this favourable condition, the usual correction for eccentricity must be applied when observing very precipitous vertical angles. We use the formula, $S = R \pm \frac{x}{c}$, in which S is the correct angle sought; R, the angle read; $x$, the amount of eccentricity; and, $c$, the length of the course as measured from the centre of the instrument to the station.

With a properly constructed and nicely adjusted side auxiliary telescope, this operation is greatly facilitated; but while horizontal angles cannot be correctly determined with it, except by similar correction or double reversed readings, the writer believed it to be the more common of the two distinct types.

The writer did not know that such instruments as these had been common in France, but by degrees, the Germans have adopted the side auxiliary telescope in connection with their concentric models, and have carried it to such perfection that, the writer regretted to say, it had temporarily eclipsed the American, leaving apparently nothing more to be desired in the mechanical construction of this type.

Fig. 31 represents the design of the side auxiliary attachment as introduced by Mr. Breithaupt of Cassel in 1892,* which, together with some of the desirable features to be found in Fig. 30, forms a part of the improvement that may justify Mr. Hoskold's remarks concerning the writer's own instrument. This side auxiliary is quickly and safely attached to an extension of the horizontal axis, and is adjustable to the zero of the vertical circle by the two small opposing screws, which are to be seen operating upon a part of the shank close by it. The small outer projection at the hub of the auxiliary contains the opening through which the cross-webs may be illuminated. As is common in Europe, the telescopes are

* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1892, vol. xl., page 251.

focussed by movement of the ocular tube, which in most cases may be drawn out so far as to make objects visible within 3 feet. The upper part of the instrument is detachable from the *dreifuss* by opening the set-screw, which appears prominently just below the

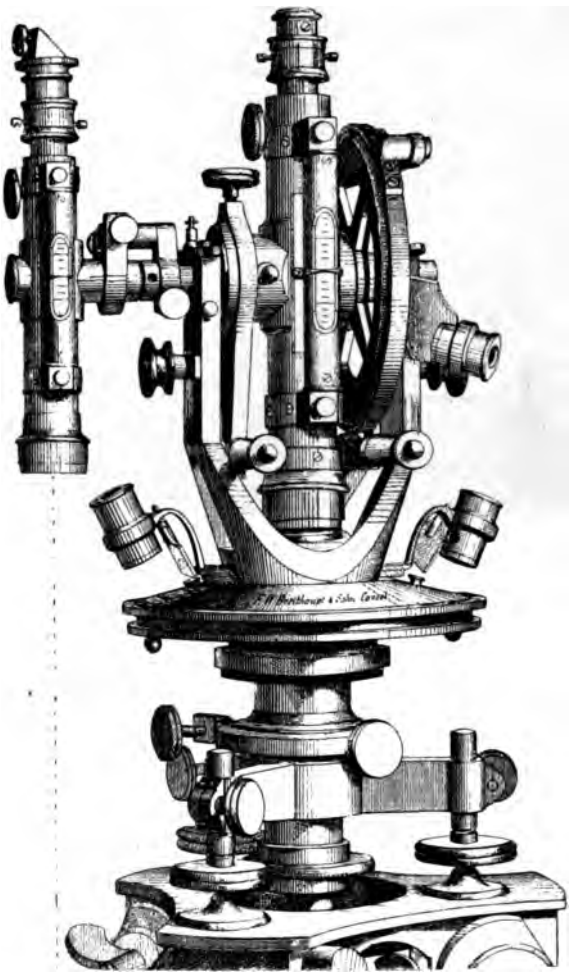


FIG. 31.—THE BREITHAUPT MINE-THEODOLITE WITH DETACHABLE AND ADJUSTABLE SIDE AUXILIARY TELESCOPE.

plates, and is interchangeable with the signal-targets, or levelling-rods in other tripods, according to the German practice now more than a century old. The auxiliary bubble, which has not been common in America, is of great convenience in testing and main-

taining the adjustment, by which both telescopes revolve in the same visual plane.

*Dunbar-Scott Mine Tachymeter.*—Before entering upon any remarks concerning the writer's own instrument, he wished to preface them by the emphatic assertion that he had no selfish interest in their sale. Englishmen will possibly also doubt that he had any claim to originality of ideas in connection with it, for Mr. Bennett H. Brough, in the last edition of his work had credited the invention to the writer's friend Mr. Denton.* But what does it matter to the engineering profession who invents instruments or devises methods, so long as they are made subservient to our common good?

The writer first saw the instrument above described in 1894, while among the iron-mines of the Gogebic range in Michigan, and it was then that the idea of an interchangeable and adjustable auxiliary telescope occurred to him. This was communicated to Messrs. Buff & Berger,† who completed the first instrument in 1896. A dissected view is presented in Fig. 32, together with an adaptation of the idea to a light 4 inches mountain-transit.

The improvement consists mainly in the interchangeability of the auxiliary telescope, which may be used at the top or at the side of the main telescope as occasion demands; thus combining two negative conditions in a single positive result. In other words, this instrument is calculated to perform the most difficult problems to be encountered in shaft-surveying, with the greatest possible facility and without the corrections for eccentricity that have previously been necessary in the employment of either of the earlier types of regular top or side auxiliary telescope. This is accomplished by simply extending the horizontal axis sufficiently beyond the bearings so as to terminate in a threaded hub. Open vertical pillars are cast in one piece with the hub of the main telescope of exactly the same length as the horizontal axis thus extended. The auxiliary telescope has a peculiarly constructed hub, which may be quickly and firmly applied to the threaded extension of either the horizontal axis or of the vertical pillars, and rapidly ranged into the same visual plane with the main

* *Engineering Mining Journal*, New York, 1896, vol. xli., page 183.

† The individual firms are now known as Messrs. C. L. Berger & Sons and the Buff & Buff Instrument Manufacturing Company, both of Boston, Massachusetts.

strument, the little cap which protects the threads, to which the auxiliary is screwed, appears prominently. The telescope-bubble is set well forward, in order to be observed with greater ease and

Fig. 34. Dunbar-Scott Mine Tachymeter, after Messrs. Brandis and Sons.

to prevent the necessity of cutting away so much of the under side of the objective-slide. The weight of this 5 inches instrument is 12·56 pounds (5·7 kilogrammes), the extension-tripod weighing 9·48 pounds (4·3 kilogrammes) more.

Fig. 33 shows Mr. Buff's application of the device to the regular type of American engineers' transit with the compass, to which many, indeed most, engineers still adhere, for in general practice it is a valuable adjunct; though, for strictly high-class mine-surveying, it is of little or no consequence. The eye-piece of each telescope is preferably of the inverting kind. Originally, it was intended that the auxiliary telescope should have but one spider-

FIG. 33.—DUNBAR-SCOTT MINE TACHYMETER, AFTER MR. BUFF.

line upon its diaphragm, which should be vertical when on the top and horizontal when at the side: for, in reality, but one line is used by virtue of the fact that the auxiliary telescope is applied to the side only when a precipitous vertical angle is to be taken, and on the top only when a horizontal angle is to be read, where one of the sides dips extremely below the horizon. In Mr. Buff's in-

the vertical circle are supplied in what is known as the "cloth finish," which reduces the expansion or contraction of the metal in varying temperatures, though it is not recommended for use in mines, as it cannot be successfully cleaned. The diagonal eye-piece has been furnished with this model, to suit some customer of Mr. Hoskold's tastes; but with an ocular prism and such a man auxiliary telescope, the writer could not see the absolute necessity of such an attachment.

Recently, the writer conducted a survey in the St. Clair shaft of the Phoenix copper-mines, in which some of the upward sights were as great as 84 degrees. The alignment was established by adjusting the auxiliary telescope to the top, and the true vertical angle read by removing it to the side. In each case, the ocular prism, which fits either telescope, was used, and with very satisfactory results. The Brandis instrument was made for one who also preferred fixed reading-glasses, which for minute-graduations on a 5 inches circle seem not only superfluous but in the way; and especially is this apparent if one tries to place a candle near enough to the eye to illuminate sufficiently for reading.

The writer supposed that small dry-storage electric lamps were best adapted for this purpose. Fig. 35 is a photograph taken on the thirteenth level of the Montreal mine, in northern Wisconsin, for the purpose of showing the application of two small electric lamps that have of late years been adopted by some American engineers. The one in the hands of the operator is made by the American Endoscopic Company, Providence, Rhode Island. It fits the pocket nicely, measuring 6 inches by 3 inches by 1½ inches, and weighs 1¼ pounds. Another, made by Mr. E. E. McIntyre, of Pittsburg, Pennsylvania, is shown pinned to the hat of the assistant. The battery of this lamp is strapped about the waist, and weighs about 3 pounds.

Of course, if one is conducting a magnetic survey, these lamps should be kept as remote as any other electric or metallic apparatus of iron or steel. In view of the frequency with which electrical appliances are being introduced into all large mines throughout the world, the mining transit of the future will be one in which the compass will be forced to give way to the artistic and more sturdy types of the U-standards such as that shown in Fig. 36.

This instrument is made by Messrs. Wittstock with a detachable trough-box compass weighing 3½ ounces. This is applied by

means of clamps to the side of the standards, although it could be placed beneath the horizontal plates according to the English

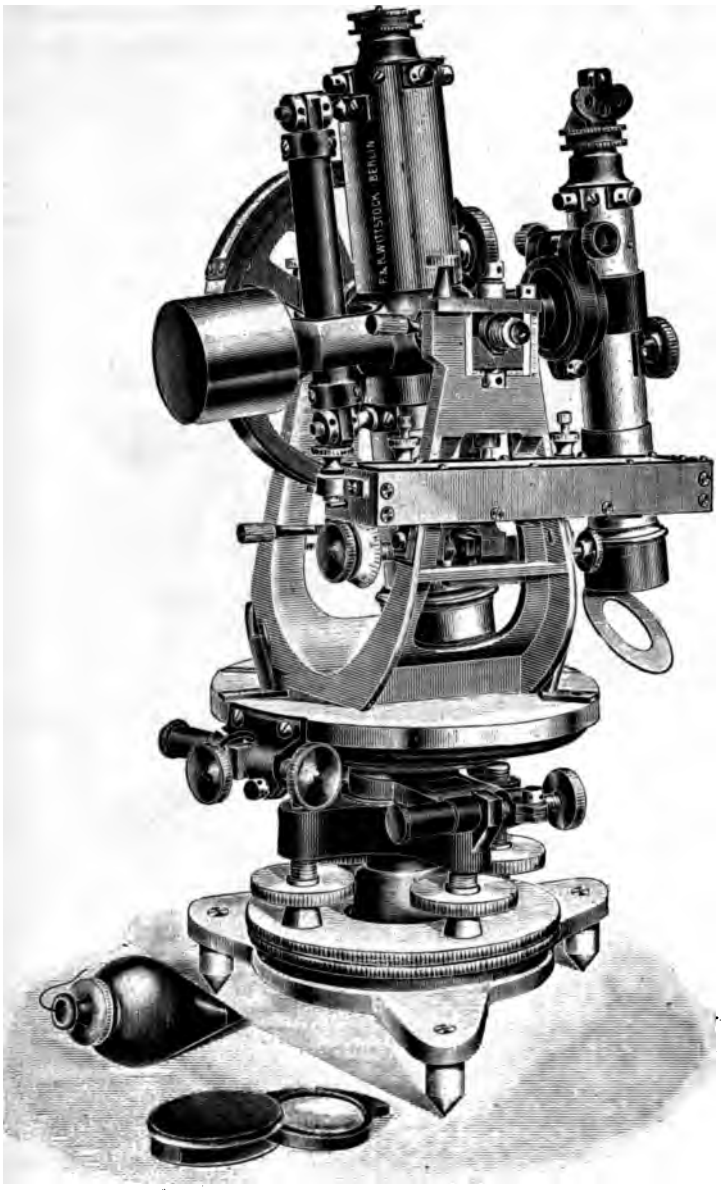



FIG. 36.—DUNBAR-SCOTT MINE TACHYMETER, AFTER MESSRS. WITTSTOCK.

custom. Both circles in this instrument are 4 inches in diameter. The main telescope is 7½ inches long, and from 18 to 22 diameters

power as may be desired. The interchangeable auxiliary telescope is $4\frac{3}{4}$ inches long and of 10 diameters power. Either may be focussed down to 3 feet. In the illustration, the counterpoise, which is always to be attached opposite the auxiliary telescope,

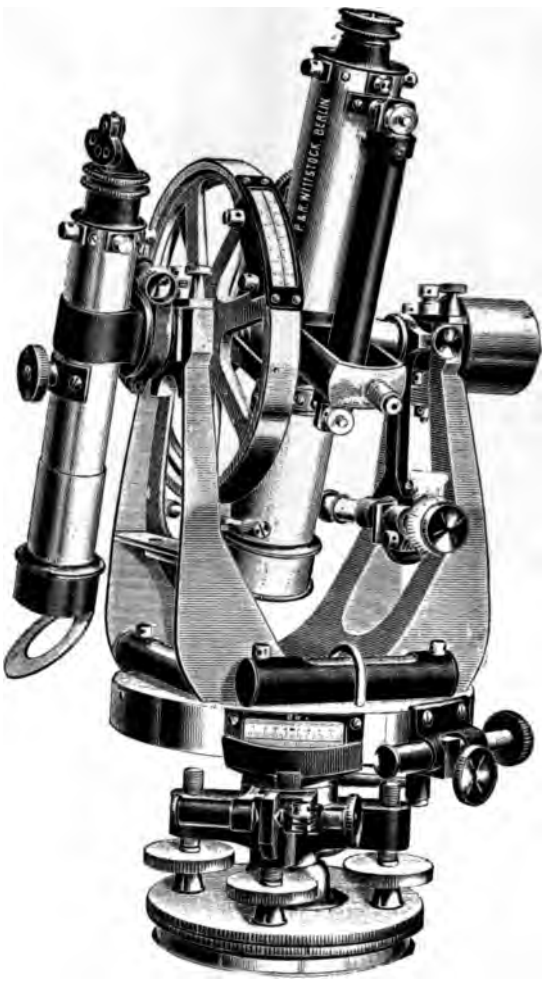



FIG. 37.—DUNBAR-SCOTT MINE TACHYMETER, AFTER MESSRS. WITTSTOCK, WITH EDGE GRADUATIONS TO BOTH CIRCLES.

appears prominently. It weighs but a few ounces, but always remains in the transit-case, with the auxiliary telescope, except when the special occasion demands their use. In ordinary work, the threaded extensions to the pillars and the extended horizontal

axis are protected by the small caps to which the writer had called attention. The weight of the instrument, complete as shown in Fig. 36, is 8¾ pounds, and the extension-tripod weighs 5½ pounds.

Special attention is directed to the edge-graduation of both circles in Fig. 37, and particularly to the convenient position of the vernier of the vertical circle. There is nothing especially new in this practice, but it is believed that this is the first time that it has been employed in mining instruments, unless some models of the Combes *théodolite souterrain* takes precedence. It is to be wondered why it has not been employed before, for nothing more convenient than this style of vertical circle can be imagined. If one is in a cramped position in a steep inclined shaft, he need not move out of his tracks to read any angle that he has observed. This was the writer's idea in placing the verniers of the horizontal circle as they were shown in Fig. 32, or only slightly off the line of sight as in this case. Here also is shown the possibility of attaching the auxiliary telescope to the left-hand side of the instrument, if necessary, and in such a case it would be very awkward to read a vernier placed, as usual, between the upright members of the standards. The reflector-cap of the vernier of the horizontal circle may be closed over the curved glass window when not in use. The edge-graduation is of greatest advantage in the 4 inches models, for it occupies a position upon the greatest possible diameter of the circle.

The dimensions of the instrument shown in Fig. 37 are as follows:—Horizontal circle, 5 inches; vertical circle, 4½ inches; main telescope, 20 to 25 diameters power and 8 inches long; auxiliary telescope, 12 diameters power and 5½ inches long; weight of instrument, complete, 8½ pounds, and of the extension-tripod, 6 pounds additional.

*Valedictory.*—It is needless to say that this article is neither from the pen of a critic nor from that of an authority; but from one who professes to be only a student, who has been striving for the best ideas and appliances, no matter whence they emanate. It has been suggested to the writer that Englishmen have no sympathy with anything that has not originated in England, but this seems to cramp the argument into a groove too narrow to contain us all and to embrace a flat denial of the fact that ideas could accompany the foreign element which is so prominent in

the very language that we speak. Prof. Huxley once said, "I have no sympathy with chauvinism of any kind, but surely of all kinds, that is the worst which obtrudes pitiful national jealousies and rivalries into the realm of science."

What the author has written here, he repeats, is intended to have no bearing whatsoever on trade, nor is the prelude of his argument designed as a plausible excuse for the advertisement of his own ideas through the effective medium of the *Transactions*.

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Mr. BENNETT H. BROUGH (London) thought that the members were to be congratulated on having secured so valuable a paper as that presented by so distinguished an American mining-engineer as Mr. Dunbar D. Scott. Written with judicial acumen and ripe scholarship, it gave the most accurate and impartial history of the development of mine-surveying yet available. Moreover, its value was enhanced by the copious references made with studious care, for these references enabled anyone desirous of deciding upon any question of priority to consult the original works. The invention of the interchangeable telescope that might be used either as a side or top telescope was one of the greatest importance; and he (Mr. Brough) much regretted that in writing on the subject he should have erroneously ascribed the invention to Mr. F. W. Denton, who published the first account of it,* instead of to the author. With regard to the use of the three tripods, in compass-surveying underground, he could not agree with the author that the method had no economic merit. For ordinary surveys it was exceedingly rapid, while permanent points for future reference could without difficulty be marked at intervals. For educational practice, all who had had experience with students underground would agree, it was most useful, as careless mistakes and accidental displacement of the tripods were easily rectified. For underground theodolite-surveys, in which excessive accuracy was required, the author was doubtless well-advised in prefering the marking of every station. He regretted that the author in his valedictory remarks should appear to think that Englishmen had no sympathy with anything that had not originated in England, but that suggestion happily applied only in very exceptional cases. The author's researches clearly showed

* *Engineering and Mining Journal*, 1896, vol. lxi, page 183.

how much British mine-surveyors owed to their fellow-workers of other nationalities, ever since the introduction of the co-ordinate system of plotting and of trigonometrical calculation by the German Reinhold in 1574, down to the author's own recent invention of the interchangeable telescope. It was, therefore, sincerely to be regretted that there should be on record in the *Transactions** of this Institution an assertion that neither the French, Germans nor North Americans had instructed Englishmen in anything new that related to surveying-instruments and surveying.

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The PRESIDENT (Mr. J. S. Dixon) moved a vote of thanks to Mr. Dunbar D. Scott for his interesting paper on surveying instruments.

Mr. C. C. LEACH seconded the resolution, which was cordially approved.

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Mr. A. A. ATKINSON's paper on "Working Coal under the River Hunter, the Pacific Ocean and its Tidal Waters, near Newcastle, in the State of New South Wales," was read as follows:—

* *Trans. Inst. M.E.*, vol. xxi., page 411.

# WORKING COAL UNDER THE RIVER HUNTER, THE PACIFIC OCEAN AND ITS TIDAL WATERS, NEAR NEWCASTLE, IN THE STATE OF NEW SOUTH WALES.

By A. A. ATKINSON, H.M. Inspector of Mines.

## Introduction.

Although coal is being worked under the sea along the coasts of the counties of Northumberland, Durham, Cumberland, Carmarthenshire and Flintshire in England and Wales, and also to some extent off the coast of Linlithgowshire in Scotland, the only paper dealing with this matter in the *Transactions* is written by Mr. H. M. Cadell, on submarine mining in the Firth of Forth, with an occasional mention that coal is worked under the sea at collieries visited by the members of the Institute.

Mr. Thomas Bell, late H.M. inspector of mines for the South Durham district,* wrote a paper which contains many useful particulars respecting the working of coal under the sea along the coast of Durham, and also inland under the Magnesian Limestone (which holds large quantities of water) in the same county.

The information respecting the collieries, contained in Appendix III., has been compiled from Mr. Bell's paper, with the exception of that relating to the Walker and Wylam collieries in the county of Northumberland.

In Great Britain, "the minerals found on and under the seashore [the area between the ordinary high- and low-water marks] belong to the Crown, or to the lord of the manor, in the absence of other established ownership;"† but, in New South Wales there are no such relics of our feudal ancestors: all coal beyond high-water mark, and so far out to sea as it may be mined, belongs to

* *Transactions of the Manchester Geological Society*, 1899, vol. xxvi., pages 366 to 399, and 554 to 559.

† *A Treatise on the Law of Mines and Minerals*, by Mr. W. Bainbridge, 1867, third edition, page 10.

how much British mine-surveyors owed to their fellow-workers of other nationalities, ever since the introduction of the co-ordinate system of plotting and of trigonometrical calculation by the German Reinhold in 1574, down to the author's own recent invention of the interchangeable telescope. It was, therefore, sincerely to be regretted that there should be on record in the *Transactions** of this Institution an assertion that neither the French, Germans nor North Americans had instructed Englishmen in anything new that related to surveying-instruments and surveying.

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The PRESIDENT (Mr. J. S. Dixon) moved a vote of thanks to Mr. Dunbar D. Scott for his interesting paper on surveying instruments.

Mr. C. C. LEACH seconded the resolution, which was cordially approved.

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Mr. A. A. ATKINSON's paper on "Working Coal under the River Hunter, the Pacific Ocean and its Tidal Waters, near Newcastle, in the State of New South Wales," was read as follows: —

* *Trans. Inst. M.E.*, vol. xxi., page 411.

the Mining Act, 1874. The rent payable for these areas is 5s. per acre per annum, and the leases carry a royalty at the same rate as those under ocean or tidal waters, with a similar concession regarding small coal. Leases may be applied for in terms of the Mining Act Further Amendment Act, for any reserved land fronting the ocean, and the rent charged is at the rate of 2s. per acre per annum, if any part of the surface is required, or 1s. 6d. per acre per annum if no part of the surface is required, and the royalty is the same as in the other cases previously mentioned.

FIG. 22.—NOBBYS, WITH BREAKWATER IN FORE-GROUND.

The physical characteristics of the area embraced in these notes, although not naturally beautiful, present many features of considerable interest, such for instance as Nobbys (Fig. 22), a prominent headland at the mouth of the Hunter river, forming with its lighthouse, a useful beacon. Southward from that point are Signal hill (120 feet above high-water mark), and Shepherds hill (250 feet above high-water mark) with precipitous cliffs, abutting on to the coast-line, decreasing in height towards Merewether; these high lands, being close to the ocean, afford some protection to the city of Newcastle from the south-easterly gales, and at the same time serve to relieve the otherwise flat

nonotony of the landscape in the immediate neighbourhood (Fig. , Plate XXIX., and Fig. 7, Plate XXX.).

The remainder of the area is either covered by the waters of he river Hunter and its tributaries, or by alluvial deposits of sand nd gravel, which, in places, are found to extend from the surface o a considerable depth (Appendix VII.).

## Geology.

Beyond the appearance of an igneous dyke at Nobbys and the utcrops of coal-seams at the same place, and in the cliffs a little arther south, there is not much of geological interest appearing at he surface near Newcastle.

The sinking of shafts, however, and the prosecution of coal-nining operations have revealed many geological features of nterest, some of which have proved themselves to be obstacles ntailing considerable engineering skill on the part of the colliery-nanager and expenditure by the owner. Among these may be nentioned: —

(1) The large number of igneous (dolerite) dykes, and their njurious effects on large areas of coal. It may be mentioned hat at one colliery, £15,102 have been spent during the past ix years in dead-work in dykes and cinder-coal.

(2) Coal-mining operations have been rendered difficult and langerous in the vicinity of the outcrop of the seam, in conse-uence of alluvial deposits occupying the channels of old streams hich have denuded the Bore-hole coal-seam, or which are found n close proximity overhead. These deposits or "washes," have sually proved to be heavily charged with water, as the coal in his area is all found below high-water mark, and surrounded by he river Hunter or its tributaries.

(3) Great variations in the thickness of the Bore-hole coal-seam, he only one extensively worked in the area under review; also f the "morgan" stone or shale found in the seam, at places only few inches in thickness, while at P in the workings of Stockton olliery (Fig. 7, Plate XXX.; and Fig. 13, Plate XXXII.) it has hickened to nearly 80 feet. The sections detailed in Appendix III. illustrate this feature.

(4) The undulations or variations in the dip of the Bore-hole oal-seam are considerable. In the workings of the Hetton colliery, here are at present 13 small pumps used to raise water out of

these swalleys or basins, and none of them are working with a vertical head of more than 40 feet. The usual dip of the strata near Newcastle is about 1 in 36 and varies from south-east to south-west.

(5) Thick deposits of clay, at some points, between the surface and the Bore-hole coal-seam, and its absence at others. It may be observed that there is an absence of clay near the outcrop of the Bore-hole seam in the north-western portion of the area, and also in the bore-holes of the Australian Agricultural Company on the ocean-beach near to high-water mark. This latter feature is particularly unfortunate, as it would lead one to conclude that the clay will not be found in the strata between the Bore-hole coal-seam and the bed of the ocean near this point, where its presence would have afforded great security to the mining operations.

(6) The absence, so far as has yet been proved, of any fault with a throw or displacement of more than 60 feet.

Although valuable papers on the New South Wales coal-fields have been written by Mr. Henry T. Plews,* Mr. G. Blake Walker,† Mr. S. H. Cox,‡ and Dr. J. R. M. Robertson,‖ the writer will transcribe Prof. T. W. E. David's classification of the Permo-Carboniferous coal-measures, near Newcastle, from the *Mineral Resources of New South Wales*, by Mr. E. F. Pittman, government geologist, as follows:—

| No. | Description of Strata. | Thickness of Strata. Feet. | Aggregate Thickness. Feet. |
|---|---|---|---|
| 1. | Upper or Newcastle Coal-measures, containing an aggregate thickness of about 100 feet of coal ... | 1,150 | 1,150 |
| 2. | Dempsey Series of freshwater beds, containing no productive coal-seams. This series thins out in certain directions ... ... ... ... ... | 2,000 | 3,150 |
| 3. | Middle, Tomago, or East Maitland Coal-measures, containing an aggregate thickness of about 40 feet of coal ... ... ... ... ... ... ... | 570 | 3,720 |
| 4. | Upper Marine Series. It is especially characterized by the predominance of the *Productus brachytherus* | 5,000 | 8,720 |
| 5. | Lower or Greta Coal-measures, containing an aggregate thickness of about 20 feet of coal ... .. | 130 | 8,850 |
| 6. | Lower Marine Series. It is especially characterized by the predominance of the *Eurydesma cordata* ... | 4,800 | 13,650 |

* *Trans. N.E. Inst.*, 1858, vol. vi., pages 27 to 48.

† *Trans. Inst. M.E.*, 1891, vol. ii., pages 268 to 320

‡ *Ibid.*, 1891, vol. ii., pages 321 to 340.

‖ *Ibid.*, 1892, vol. iv., pages 83 to 109.

The following are the principal coal-seams occurring in the Upper Coal-measures, near Newcastle, in descending order, as given by Mr. E. F. Pittman:—

| No. | Name of Coal-seam. | Thickness. Feet. |
|---|---|---|
| 1. | Wallarah coal-seam ... ... ... ... ... ... ... | 11 |
| 2. | Four-feet coal-seam ... ... ... .. ... ... ... | 4 |
| 3. | Catharine Hill Bay coal-seam ... ... ... ... ... | 14 |
| 4. | Great Northern coal-seam ... ... ... ... ... ... | 20 |
| 5. | Burwood coal-seam, varies from ... ... ... ... | 6 to 8 |
| 6. | Dirty coal-seam, varies from ... ... ... ... ... | 6 to 10 |
| 7. | Yard coal-seam ... ... ... ... ... ... ... ... | 3 |
| 8. | Bore-hole coal-seam, usually 8 to 9 feet, but it varies from 4 to 22 | |

The four lower seams are the only ones found in the area described in this paper.

The Burwood coal-seam is found cropping out in the hills near Merewether, and is worked on a small scale at one tunnel or adit colliery.

The Dirty coal-seam, as its name indicates, has at present no commercial value, and is not being worked.

The Yard coal-seam produces a good coal, and although it was worked in the early days of coal-mining near the city of Newcastle, it is not now being worked.

The Bore-hole is the most extensively worked and the most valuable coal-seam in these measures, and it is found of the greatest thickness and of the highest quality near the city of Newcastle. The northern district of New South Wales produced in 1900 3,926,584 tons of coal, and of this quantity 3,221,928 tons were wrought from the Bore-hole seam.

## Collieries.

Operations in the Bore-hole seam were commenced by the Australian Agricultural Company, who are now working the New Winning or Sea pit; and the other collieries now working this seam in this area are the Newcastle Coal-mining Company at their A and B Pits, the Hetton colliery, the Wickham and Bullock Island colliery and the Stockton colliery.

An average analysis of coal of the Bore-hole seam from these collieries is recorded by Mr. E. F. Pittman* as follows:—

* *Mineral Resources of New South Wales*, 1901, pages 324, 329, 330, 333, 337 and 340.

| | Per cent. |
|---|---|
| Hygroscopic moisture ... ... ... | 1·59 |
| Volatile hydrocarbons ... ... ... | 37·46 |
| Fixed carbon ... ... ... ... ... | 54·43 |
| Ash ... ... ... ... ... ... | 6·52 |

The average sulphur-content is 0·417 per cent. The mean specific gravity is 1·299. The mean yield of coke is 60·95 per cent. The mean evaporation, by 1 pound of coal derived from these collieries, is 13·29 pounds of water.

At present, the only collieries working coal beyond high-water mark are the Stockton, Hetton, New Winning or Sea pit of the Australian Agricultural Company, and the A and B pits of the Newcastle Coal-mining Company.

Farther south, the Scottish Australian Mining Company intend to work sea-coal from their Burwood and Lambton B pits, while the Dudley Coal Company intend to work their ocean coal, between the two properties of the Scottish Australian Mining Company. Nothing, however, has yet been done by these two companies in this coal, as their workings are still a considerable distance from high-water mark.

In the neighbourhood of Tighes Hill, several small collieries commenced operations, about 1880, in the Bore-hole coal-seam near the outcrop. At a later date, the Ferndale, Linwood, Stockton, Wickham and Bullock Island, and Hetton collieries commenced working coal farther to the dip, under the estuarine deposits of the river Hunter. All these collieries, with the exception of Stockton, Hetton, and Wickham and Bullock Island, have ceased operations; these three are sometimes known as the "delta collieries."

## Inundations.

In consequence of the uncertain character of the roof of the Bore-hole seam in the neighbourhood of the outcrop, the alluvial deposits of sand and gravel being sometimes found lying directly on the top of the coal, whilst in places the coal is entirely denuded or washed out; and as the sand frequently contained large quantities of water derived from the tidal waters of the river Hunter, mining operations were carried on in the vicinity of the outcrop of the seam with great anxiety and considerable risk to life.

In 1886, the water from Throsby creek, in consequence of a fall of the roof, found its way into the Ferndale colliery, by which a miner lost his life; and his body was not recovered, as the workings have not been drained since the inundation.*

This accident led to the appointment of a Royal Commission to enquire into the circumstances in connection with the accident at Ferndale colliery, and subsequently another Royal Commission reported on the *Condition of the Collieries adjacent to Ferndale.* The latter report embraced enquiries into the conditions then existing at all the collieries, now under review.

### Mining Coal under Tidal Waters or under the Sea.

Appendix II. contains a copy of the special conditions which are included in all leases and authorities to mine for coal under the river Hunter or tidal waters, or under the ocean, granted subsequent to the date of these reports.

Having regard to the remarks of the Royal Commission in the first paragraph of their report (Appendix I.) in respect of "a minimum thickness of solid strata . . . between the top of the coal and the bed of the ocean,"† it is unfortunate that they did not offer some definite recommendations on this point.

The writer understands that the mining engineer acting for the Crown coal in Great Britain has arranged in one instance that coal shall not be worked under the ocean, unless there is at least 126 feet of strata between the bed of the sea and the top of the coal-seam that is being worked; and that in no case shall the pillars of coal be removed, or the longwall system adopted at this colliery where there is less than 360 feet of intervening strata.‡

Provision is also usually made for leaving a fixed width of coal adjacent to faults where the throw or displacement of the seam exceeds a defined distance. It would be interesting to know if these regulations are varied where the conditions of working are different, such as, for example:—(1) Having regard to the

* The approximate section of strata was:—Surface sand and silt, 23 feet; clay, 2 feet; conglomerate, 12 feet; and post, 28 feet. *New South Wales: Royal Commission on Collieries, Report on the Accidents at Ferndale Colliery*, 1886, Sydney, page 17.

† *New South Wales: Royal Commission on Collieries, Third Report on the Condition of the Collieries adjacent to Ferndale*, Sydney, 1886, page 67; and *Trans. Inst. M.E.*, 1902, vol. xxiii., page 636.

‡ Leases are in force allowing the entire removal of the coal-seam, under a minimum thickness of cover of 270 feet below the bed of the sea under specified conditions.—Editor.

presence or absence of beds of clay between the water and the top of the coal-seam; and (2) the thickness of the seam being worked, and its power to resist crushing.

The value of thick beds of clay between the seam and the bed of the river Hunter has on several occasions been demonstrated in connection with the working of the delta collieries, as will be shewn hereafter.

### Methods of Working.

All the six collieries, working in the area referred to in these notes, have adopted the bord-and-pillar system, whether the operations are being conducted under land or under water.

In the Stockton, Hetton, and Wickham and Bullock Island collieries, the bords are driven 18 feet wide and the headings, walls or cut-throughs, stentons and narrow or winning bords are usually 9 feet wide. The pillars of coal are usually left 24 or 27 feet thick, and vary in length from 60 to 90 feet.

In one district of one of these collieries, the seam is separated by a thickness of stone, varying from 20 to 80 feet, into two portions. The bottom seam was worked some years ago, by means of bords 18 feet wide, and pillars of coal 18 feet thick; and the top seam is now being similarly worked, care being taken to ensure that the pillar in the top seam is placed immediately overlying that in the bottom seam. This is considered to afford greater security than by increasing the width of the pillar in the top seam. It may be mentioned that this coal-seam is being worked under land.

Where winning or advanced places are being driven in pairs, the coal-pillar between them is generally 33 to 36 feet thick, and the stentons are placed about 90 feet apart.

In these collieries, therefore, about 50 per cent. of the coal is got in the whole or first working, and the remainder is left in the pillars.

A few years ago, in consequence of the pillars left not being sufficient to carry the weight of the superincumbent strata, all of these collieries were subject to crushes or thrusts, in the areas shewn on the plan (Fig. 7, Plate XXX.). But in no case has there been a creep or rising of the floor, which is composed of very hard grey sandstone.

Appendix V. contains information as to crushes that have occurred at the Hetton, Stockton, and Wickham and Bullock Island collieries. No partial or serious crushings of the pillars in these three collieries had occurred since October, 1897, as the experience gained in the method of working had resulted in precautions being adopted to prevent their recurrence.

Except in the instance already mentioned, where bords, 18 feet wide, and pillars, 18 feet thick, had been formed in the bottom seam, since October, 1897, no pillars had been made less than 24 feet thick, and no bords had been driven more than 18 feet in width. It would appear that these conditions are sufficient to maintain the superincumbent strata of the present thickness.

Where the Bore-hole seam is thick, say from 12 to 15 feet, in some instances it has been found advisable to leave the "top-band coal," about 4 feet thick to strengthen the roof. This is particularly useful in cases where the roof is friable, and after exposure, has a tendency to decrepitate over the edges of the pillars, which in turn, especially where the coal is tender, crumble, and are thus weakened and, therefore, are less able to withstand the pressure which they are required to support.

It is worthy of notice in connexion with these crushes, that in no case had any water been admitted into the workings, although in several instances abundant proof was afforded of the occurrence of crushes by damage to buildings, etc., on the surface. This security is doubtless due to the existence of thick, impervious beds of clay, between the Bore-hole seam and the surface, preventing the water from passing into the workings.

The quantity of water that is being pumped from these collieries, having regard to the shallow depths and to the fact that the workings are to a great extent under surface-waters, is very small, and varies from 50 gallons per minute at one to 660 gallons per minute at another. In nearly every case, the water is either brackish or decidedly salt; but at one place, in the Hetton colliery, under the mouth of the river Hunter, the water is nearly fresh, and the mine-horses are allowed to drink it.

The only occasion, so far as the writer is aware, when any considerable quantity of water (200 gallons per minute) was suddenly encountered in any of these three collieries, was after a fall of roof in the Stockton colliery in 1893. This fall is near the point

marked X (Fig. 7, Plate XXX.) The bottom portion of the seam was being worked, and the appearance of sand and gravel from the fall led to the conclusion that the top part of the seam had been denuded, and that its place had been taken by alluvial detritus. A little fire-damp was given off on this occasion, the first recorded occurrence in any of the delta collieries.

In the A and B pits of the Newcastle Coal-mining Company, the bords are usually driven 24 feet wide, and the pillars are left 24 feet thick when working coal under the land; and under the sea it is proposed to leave pillars of the same size, but the width of the bords is reduced to 18 feet.

In the New Winning or Sea pit of the Australian Agricultural Company, the bords are driven 18 feet wide, and the pillars are 36 feet thick under the land, and under the sea the same system will be carried out.

So far as these two companies have yet worked the coal under the sea, the top-band coal had been left next to the roof, and the thickness of the seam worked varied from 7 to 9 feet.

### Safe Limit of Working Coal under the Ocean.

In attempting to come to a decision as to what may be regarded as the safe limit of working coal under the ocean near Newcastle, it appeared to the writer that the following matters should have due consideration, and on this important question he had received valuable assistance from Mr. E. F. Pittman, and from the district inspectors of collieries:—

(1) Character of the overlying strata, with special reference to loose deposits of alluvium or beds of clay between the bed of the ocean and the coal-seam.

(2) Presence of faults and dykes in the strata.

(3) Dimensions of pillars to be left and the width of openings to be made, or in other words, the percentages of coal to be left and worked respectively. The question of longwall may be altogether omitted, as the conditions under the ocean, near Newcastle, do not admit of its consideration.

(4) And the utility of leaving coal, next to the roof, in some cases.

The writer offers the following remarks in regard to the fore-
›ing points:—

(1) The character of the strata near the coast is given in the
›tailed sections (Appendix VII.), and it is also diagrammatically
lustrated by the vertical lines of sections (Figs. 8 to 21, Plates XXI. and XXXII.). The most noticeable features in these
›e:—

(*a*) The great thickness of the alluvial deposits towards the
›rth of the Stockton estate, and fortunately, as shown by the
ction in the No. 3 shaft, a considerable thickness of clay.

Having regard to the character of the strata near the No. 3
ıaft, it appears probable that the river Hunter, in former days,
ıd run through this narrow neck of the peninsula into the ocean.

In consequence of the alluvial deposits in this vicinity, it has
›en arranged with the management to put up vertical bore-holes,
) feet above the coal, at distances of 300 feet apart in the next
innings under the ocean—in addition to the intermediate bore-
›les of 30 feet at distances of 60 feet apart.

(*b*) The Stockton working-shaft appears to be sunk in the
›ttom of the basin, the coal-seam rising from it in every direction.

(*c*) The absence of clay in the bore-holes put down near to
ıgh-water mark on the estate of the Australian Agricultural
›mpany, and the probability of the same absence near the coast
ıd under the ocean on the estate of the Newcastle Coal-mining
›mpany. In consequence of this, it has been arranged with the
›tter company to put down a bore-hole on their property near to
ıgh-water mark, in order to afford information as to the probable
ıaracter of the strata that will be found between the bed of the
›ean and the Bore-hole coal-seam.

(*d*) The low-lying area between Shepherds hill, the B pit of the
›ewcastle Coal-mining Company, and the south end of Throsby
›eek, together with the considerable thickness of alluvial
›posits found therein, point to the probability that the river
Hunter, in former times, had an outlet to the ocean to the south-
›est of Shepherds hill.

(2) It is well known that the geological agencies operating in
ıe formation of faults and dykes have assisted in making suit-

able channels for passing water to lower levels in their vicinity. It is therefore not by any means an uncommon occurrence in mining to obtain large feeders of water when crossing dykes and faults, when otherwise the workings are quite dry. It is for this reason that Nos. 6 and 7 of the special conditions (Appendix II.) are included in the ocean-leases.

On account of the disturbed nature of the strata in the vicinity of faults and dykes, it is advisable after proving them by bore-holes, to timber the places well, and approach them by reducing the width as much as is convenient, in order to expose the cheeks of the faults and dykes as little as possible. At Cambois colliery, in Northumberland, where bord-and-pillar and longwall are being worked under the ocean in a seam, 4 to 6 feet thick, and at a depth of about 360 feet (Appendix IV.), the custom is to leave 60 feet of coal next to faults the throw of which exceeds 18 feet, or the cheeks of which are more than 2 feet apart.

Both faults and dykes have been found under the Pacific ocean, and the writer observed that small quantities of water are frequently given off when the fissure is reached, while the adjacent strata may be perfectly dry. It is therefore evident that in working coal under the ocean, care should be exercised in crossing faults and dykes, and they should be exposed or bared as little as possible.

(3) As already described, it has been found that the pillars of the Bore-hole coal-seam have not shewn any tendency to crush or crumble when left 24 feet thick, the bords being driven 18 feet wide, where the overlying strata were 350 feet thick.

As these are the respective widths for working coal under the ocean, and as the strata over the Bore-hole coal-seam near Newcastle are not likely to exceed 350 feet in thickness, it would appear that under ordinary conditions these dimensions are suitable. It may, however, be pointed out that it is at the discretion of the manager, should he consider it necessary, to increase the minimum width of the pillars, or decrease the maximum width of the bords, in accordance with No. 1 of the special conditions (Appendix II.).

In the Stockton colliery, about 50 per cent. of the coal is left, while the Australian Agricultural Company is leaving about 61 per cent. of that portion of the seam that is being worked. In addition to this, so far, the latter company leave 4 feet of the top-

band coal next the roof under the ocean; the pillars are 96 feet long by 36 feet wide, and the bords are driven 18 feet wide.

(4) The benefit of leaving some coal next to the roof has already been referred to, and it appears that this practice is adopted in other instances, namely:—Point of Ayr and Harrington* collieries in England, and the Taupiri colliery in New Zealand. Where the roof is bad, or the coal thick and tender, there is no doubt that this has a strengthening effect.

The Australian Agricultural Company have already decided not to work any coal under the ocean with less than 140 feet of strata between its bed and the coal-seam; while the Stockton and Hetton collieries have thicknesses of about 250 and 300 feet respectively. For the present, therefore, it has only been deemed necessary in the case of the submarine workings of the Newcastle Coal-mining Company to decide upon the minimum thickness of strata to be left between the bed of the ocean and the coal-seam, and this has been fixed at 120 feet.

The vertical bore-holes into the roof above the seam are made by means of the machine shown in Figs. 2 and 3 (Plate XXIX.). Bore-holes, 30 feet long, usually cost about 2s. per foot, and a core of the strata is obtained about 1 inch in diameter. In one case, a vertical hole attained a height of 90 feet, and the writer is informed that by increasing the strength of the boring-gear, they could be driven, and a core obtained up to a length of 150 feet without great difficulty, although the cost would be considerably increased.

Appendix VI. contains a note describing the methods of sinking shafts where the sand and alluvial deposits were of considerable thickness.

In conclusion, the writer has to accord his thanks to the chief mining-surveyor, Mr. Martin, of the charting branch, the colliery-managers and the inspectors of mines, for their valuable assistance in the preparation of the plans and sections attached to this paper.

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* This statement refers to the workings in the Main Band coal-seam, and it does not refer to the seam now being worked.—EDITOR.

APPENDIX I.—SUMMARY OF RECOMMENDATIONS MADE BY THE ROYAL COMMISSION APPOINTED IN 1886 TO REPORT ON THE CONDITION OF THE COLLIERIES ADJACENT TO FERNDALE.*

The comparatively shallow depth to the lower coal-seam in the collieries enumerated, renders it necessary that the most accurate and trustworthy information should be obtained, not only of the depth of water and character of the sea-bottom, but (in collieries mining under the delta) of the thickness and character of the deposits that overlie the rock, some of which (such as clay) it has been seen add so materially to the security and safety of the mines. From a sincere desire to ensure safety to life and security to mining works, the Commission—looking to the thickness of the strata overlying the coal-seam in the case of these leaseholds (ocean) where, it is probable, no surface-deposits exist and the rock itself may form the bed of the ocean—consider that, as the workings would be extended, so to speak, towards the unknown (although it may appear arbitrary and to some extent may restrict operations), a minimum thickness of solid strata should—indeed, must—intervene between the top of the coal and the bed of the ocean. In the case of undoubted proof of strong plastic clay overlying the rock-head, due consideration should be given to that circumstance. To the north of Stockton, the surface-deposits are, so far as proven, of so ominous a nature, that, unless carefully conducted operations reveal improved conditions, the Commission do not at present see any practicable method whereby mining operations can with safety be conducted under the ocean at that part of the district.

The Commission are fully aware that, so far as they know, no restrictions such as those indicated have been as yet considered necessary in Britain or her colonies; but they are likewise unaware of coal-mining being prosecuted under similar circumstances. The peculiar conditions of the coal-fields under consideration are, in their opinion, a justification for calling attention thus early to the sources from whence danger may be apprehended. The Coal-mines Regulation Act enforces certain precautions being observed in approaching suspected danger.

The Commission cannot distinguish any reason why these precautionary measures should not be extended, with a view to avert danger from a source novel to colonial coal-mining, and not contemplated when the Act of 1876 was passed.

* * * * * * * * * *

The measure of safety, that the workers in collieries such as that indicated will enjoy, may be gauged by the degree of order, system and regularity that is insisted upon by the management. Perfect discipline and strict observance on the part of the workmen of any rule rendered necessary for the better protection of life and property, and this, with diligent, careful and regular inspection on the part of the officers appointed by the Government, will materially contribute towards this end.

The workings should be laid off systematically and conducted carefully, and the width of bords and thickness of pillars strictly adhered to; and any laxity or carelessness on the part of the workmen should be instantly met by the imposition of a suitable fine, and in the case of continued negligence, by some easily obtained and summary form of punishment.

* *New South Wales: Royal Commission on Collieries: Third Report on the Condition of the Collieries adjacent to Ferndale*, Sydney, 1886, page 67.

In the case of collieries working under the conditions anticipated, the coal-workings should be accurately surveyed every term, and the coal taken out during the previous term represented by some conspicuous colour, and the dates of such surveys affixed in ink. Colliery-plans should be a faithful and honest record of all faults and occurrences that are met with in the mine; and the workings should be delineated on them as they are, not as they were intended to be. They should also have delineated on them the leading surface or topographical features, and this applies equally to ocean-leaseholds and those on the mainland.

In one road of every pair of "winning-off" or leading headings or levels, a bore should be kept going (say) 9 feet in advance, for the purpose of foretelling the presence of any fissure, open joint or fault, or otherwise; and in the case of workings under the ocean all winning-off headings or levels should be driven at least 100 yards in advance of the working bords.

The width of the bords and the area and arrangement of pillars, while they ought in all cases to be graduated to suit circumstances, such as depth, character of roof, floor. or particular conditions overhead—in the case of collieries working under the ocean at the limited depths referred to (and without reference to the ordinary circumstances that should regulate the width and thickness or area of bords and pillars), may fairly be considered in a special light. The impossibility of calculating the conditions of the superincumbent strata and the forces that repose in the ocean, makes it necessary, in the opinion of the Commission, to increase the ordinary margin considered sufficient for the safety of a mine. As no attempt, under these circumstances, could be made to work out or recover pillars, it becomes necessary to consider the coal-pillars as so much mineral won, or impossible to recover for this reason. The size of pillars must be such as to afford ample support after exposure to the crumbling effect of the air over many years.

The Commission are therefore of opinion that the thickness of pillars should be materially increased beyond that generally considered necessary in the district. The strength of these pillars may be increased by a judicious arrangement of cut-throughs and roads, so as to have as few roads intersecting or branching from a main road at one place as possible. Zig-zagging pillars, with respect to cut-throughs, may be advisable. The width of bords in the district is 8 yards. In the case of collieries working under the above conditions, this width would, in the opinion of the Commission, court disaster. The width of bords should be materially reduced, and the greatest care taken to secure the roof with timber. In these general opinions the Commission are supported by almost every witness who submitted himself for examination. While many of these gentlemen condescended upon specific widths of bords and thickness of pillars, the Commission prefer, in the absence of particular and detailed information, to enunciate general opinion only, and to repeat that while these should be graduated or fixed by a knowledge of all the circumstances, yet it might be advisable to state that in the case of ocean-leaseholds a minimum thickness of (say) 8 yards for pillars, or a maximum width of 6 yards for bords, might be insisted upon, leaving the management free to exercise their discretion in altering these (by increasing the maximum thickness or decreasing the minimum width) so as to increase the general safety.

Knowing the tendency that "faults" possess of weakening the roof, and of permitting the passage of water through the broken material that is frequently found along their line, or through open joints in their substance, it would be well in discovering a fault or fissure in a bore to take precautions against possible danger from this source before opening it up by the drive.

In the case of some of these ocean-leaseholds it may be impossible; but when possible, the coal underlying the ocean should be attacked only after a large "goaf" has been made by extensive coal-workings under the mainland. This, in addition to special and unusual facilities being provided for the escape of men by the shafts, would afford a measure of security difficult to over-estimate.

The Commission, aware of the impossibility of preventing accidents by Acts of Parliament, and the danger of absolute rules, are confident, in pointing out some of the general lines in which protection to life and property can best be secured, and allowing ample scope for skilful management, that greater benefits will probably result than by recommending regulations of a hard-and-fast and unbending nature, that would be found in practice to be unworkable, to bear with especial severity on individuals, and to induce results detrimental to an important industry.

It is obvious that if coal-mining is to be conducted under the precarious conditions narrated, it must of necessity be guided by managers thoughtful, experienced and skilful, and under regulations and discipline that will eventually, by appealing to the reflective faculties of the workmen, impress and identify them with a sense of their individual and collective responsibility. It is possible that the chief security may be found to rest in the skill and thoughtful care of those engaged in these avocations.

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## APPENDIX II.

A.—Special Conditions in Leases for Working Coal under Tidal Waters.

(1) The minimum width of pillars to be left shall be 6 yards (now 8 yards) and the maximum width of bords or other excavations shall be 6 yards; but the lessee or manager of the colliery is free to exercise his discretion in altering the above by increasing the minimum width of the pillars or decreasing the maximum width of the bords or other excavations, so as to increase the general safety.

(2) That the 6 yards pillars shall be left unwrought.

(3) All headings and bords to be driven by plumb-lines.

(4) All coal-workings to be accurately surveyed every three months, the plan thereof to show the area worked out during the previous three months, and every year's workings must be indicated thereon by some distinctive colour. The dates of each must be noted on the plan.

(5) The colliery-plans to contain a faithful and honest record of all dykes, fissures, and occurrences that are met with in the mine, and the workings delineated thereon as they are, and not as they are intended to be.

(6) In one road of every pair of winning-off or leading headings, a bore shall be kept going 10 feet in advance, for the purpose of foretelling the presence of any fissure, wash-out, open joint, fault, dyke or otherwise, and all winning-off headings shall be driven at least 50 yards in advance of the working-bords.

(7) Owing to the tendency that faults, dykes, wash-outs, and such like possess of weakening the roof and of permitting the passage of water through the broken material that is frequently found along their lines or through open fissures, or joints, the lessee or his mining manager, must, on discovering a fault, wash-out, dyke or fissure in a bore at the face or side of the leading headings or levels, take all necessary precautions against possible danger before opening it up by the drive.

(8) In addition to the special facilities which shall have been provided for the escape of the men by the shafts, the coal under the ocean should not be attacked until after a large goaf has, if possible, been made by extensive coal-workings under the mainland.

(9) That the most accurate and trustworthy information be obtained by the lessee or his mining manager, as to the thickness and character of the strata and estuarine deposits overlying the coal-seam before commencing to work it.

B.—Special Conditions in Leases for Working Coal under the Sea.

(1) The minimum width of pillars to be left shall be 8 yards, and the maximum width of bords or other excavations shall be 6 yards; but the lessee or the manager of the colliery is free to use his discretion in altering the above by increasing the minimum width of the pillars, or decreasing the maximum width of the bords or other excavations, so as to increase the general safety.

(2) That the 8 yards pillars shall be left unwrought.

Nos. 3, 4 and 5 conditions are the same as those printed in Appendix II. A.

(6) In one road of every pair of winning-off or leading headings, a bore shall be kept going 10 feet in advance, for the purpose of foretelling the presence of any fissure, wash-out, open joint, fault, dyke or otherwise, and all winning-off headings shall be driven at least 100 yards in advance of the working-bords.

Nos. 7 and 8 conditions are the same as those printed in Appendix II. A.

(9) That the most accurate and trustworthy information be obtained by the lessee, not only of the depth and character of the sea-bottom, but also of the strata overlying the coal-seam, which strata shall be bored through, and proved a minimum thickness of 30 feet at the face of the leading headings or levels, so soon as they have been driven 100 yards in advance of the working-bords; and, after the first bore-hole has been completed, other bore-holes shall be so put up in advance of it at the face of the headings or levels, at distances not exceeding 20 yards.

APPENDIX III.—PARTICULARS OF COAL-SEAMS WORKED UNDER STRATA CONTAINING WATER IN LARGE QUANTITIES, OR UNDER THE WORKINGS OF COAL-SEAMS STANDING FULL OF WATER IN THE COUNTIES OF DURHAM AND NORTHUMBERLAND.

| No. | Name of Colliery. | Depth from the Surface to the Bottom of the Water-bearing Strata. | Name of Coal-seam being worked. | Depth from Surface. | Thickness of Coal-seam. | Depth of Coal-seam being worked below the Water-bearing Strata. | Description of Water-bearing Strata. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | Feet. | | Feet. | Feet In. | Feet. | | |
| 1 | Castle Eden * | 645 | Five-quarter ... | 715 | 4 4 | 70 | Magnesian Limestone | The water-feeders occurred when working the pillars of the Low Main seam. The feeders were usually reduced, but the last one of 1,500 to 2,000 gallons of water per minute resulted in the abandonment of the colliery. |
| | | | Main ... ... | 758 | 5 5 | 113 | do. | |
| | | | Low Main ... | 911 | 4 9 | 266 | do. | |
| | | | Hutton ... | 1,038 | 3 9 | 393 | do. | |
| 2 | Chilton * ... | 129 | Five-quarter .. | 384 | 4 10 | 255 | do. | Both seams were extensively goafed in superposed planes without bringing down any of the water-feeders. |
| | | | Main ... ... | 456 | 4 4 | 327 | do. | |
| | | | Harvey .. | 933 | 4 4 | 804 | do. | Not extensively worked. |
| 3 | Deaf Hill * ... ... | 351 | Five-quarter ... | 484 | 3 7 | 133 | do. | The Five-quarter seam has been extensively worked at a depth of 133 feet below the water-feeders. The Main, Low Main and Harvey coal-seams are also extensively worked. |
| | | | Main ... | 585 | 3 10 | 234 | do. | |
| | | | Low Main .. | 715 | 3 6 | 364 | do. | |
| | | | Harvey .... | 967 | 3 1 | 616 | do. | |

| | | Feet. | | Feet. | Feet. In. | Feet. | | |
|---|---|---|---|---|---|---|---|---|
| 4 | Haswell * ... .. | 303 | Five-quarter | 549 | 3 6 | 246 | Magnesian Limestone | Large areas of goaf have been formed in superposed planes in all seams. The Five-quarter seam has been extensively worked by the longwall system, and none of the water-feeders have been tapped. |
| | | | Main ... | 647 | 3 6 | 344 | do. | |
| | | | Low Main | 803 | 3 7 | 500 | do. | |
| | | | Hutton .. | 922 | 5 5 | 619 | do. | |
| 5 | Hutton Henry * ... | 476 | Hutton .. | 661 | 3 3 | 185 | do. | Large feeders of water were obtained, and the colliery was eventually abandoned: the intervening strata had evidently thinned southward. |
| | | | Harvey . | 807 | 5 7 | 331 | do. | |
| 6 | Kelloe or East Hetton * | 157 | Five-quarter | 342 | 4 6 | 185 | do. | |
| | | | Main ... ... | 387 | 4 7 | 230 | do. | |
| | | | Hutton ... | 672 | 2 10 | 515 | do. | |
| | | | Harvey .. | 809 | 3 6 | 652 | do. | |
| 7 | Murton * ... .. | 480 | Five-quarter ... | 1,062 | 4 9 | 582 | do. | These seams have only been partially worked. |
| | | | Main ... ... | 1,219 | 6 2 | 739 | do. | |
| | | | Low Main .. | 1,362 | 4 7 | 882 | do. | Both seams have been goafed in superposed planes over many acres. |
| | | | Hutton .. | 1,470 | 6 2 | 990 | do. | |
| 8 | Ryhope * ... ... | 323 | Maudlin ... | 1,528 | 7 2 | 1,205 | do. | Both seams have been goafed in superposed planes over many acres. The pillars were made 120 feet by 90 feet. |
| | | | Hutton ... | 1,630 | 3 9 | 1,307 | do. | |

* Information derived from Mr. T. Bell's "Notes on the Working of Coal-mines under the Sea, and also under the Permian Feeder of Water in the County of Durham," *Transactions of the Manchester Geological Society*, 1899, vol. xxvi., pages 366 to 399, and 554 to 559.

APPENDIX III.- PARTICULARS OF COAL-SEAMS, ETC.—*Continued.*

| No. | Name of Colliery. | Depth from the Surface to the Bottom of the Water-bearing Strata. | Name of Coal-seam being worked. | Depth from Surface. | Thickness of Coal-seam. | Depth of Coal-seam being worked below the Water-bearing Strata. | Description of Water-bearing Strata. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | | | Feet. | Ft. In. | Feet. | | |
| 9 | Seaham * ... ... | 515 | Main ... | 1,309 | 6 1 | 794 | Magnesian Limestone | In several places, all these seams have been goafed in superposed planes without disturbing the water-bearing strata. |
| | | | Maudlin ... | 1,361 | 5 0 | 846 | do. | |
| | | | Low Main ... | 1,427 | 5 2 | 912 | do. | |
| | | | Hutton ... | 1,528 | 4 8 | 1,013 | do. | |
| 10 | Silksworth * ... | 325 | Maudlin ... | 1,618 | 5 9 | 1,293 | do. | Both seams have been goafed in superposed planes over many acres. |
| | | | Hutton ... | 1,740 | 4 4 | 1,415 | do. | |
| 11 | Thornley * ... .. | 190 | Five-quarter ... | 507 | 3 5 | 317 | do. | In one part of the royalty, four of the seams have been worked and goafed over more than 100 acres in superposed planes. In several parts of the mine, five seams have been worked and goafed in superposed planes without bringing down any of the sand or limestone-feeders of water. |
| | | | Main ... ... | 614 | 2 9 | 424 | do. | |
| | | | Low Main ... | 739 | 3 0 | 549 | do. | |
| | | | Hutton .. | 865 | 3 2 | 675 | do. | |
| | | | Harvey ... | 994 | 3 8 | 804 | do. | |
| 12 | Trimdon * ... ... | 347 | Five-quarter ... | 407 | 3 7 | 60 | do. | This seam has been extensively worked at a depth of 60 feet below the water-feeders. |

| | | Feet. | | Feet. | Feet | In. | Feet. | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | Trimdon Grange * .. | 251 | Five-quarter ... | 360 | 3 | 9 | 109 | Magnesian Limestone | All these seams have been extensively worked and goafed in superposed planes. Feeders have never been tapped while working at a depth of 180 feet below the sand at the bottom of the limestone. |
| | | | Main ... ... | 450 | 4 | 9 | 199 | do. | |
| | | | Low Main ... | 583 | 3 | 6 | 332 | do. | |
| | | | Harvey ... | 857 | 3 | 7 | 606 | do. | |
| 14 | Walker ... .. | 600 | High Main .. | 600 | 8 | 0 | nil. | The workings in the High Main coal-seam are drowned and under a head of 500 feet of water. | The Low Main seam has been goafed at a depth of 360 feet below the drowned workings of the High Main seam. |
| | | | Low Main | 960 | 6 | 0 | 360 | | |
| 15 | Wearmouth * ... | 330 | Maudlin ... | 1,594 | 5 | 6 | 1,264 | Magnesian Limestone | Both seams have been goafed in superposed planes over many acres. |
| | | | Hutton ... | 1,725 | 4 | 6 | 1,395 | do. | |
| 16 | Wheatley Hill * ... | 380 | Five-quarter ... | 659 | 4 | 0 | 279 | do. | Both seams have been goafed in superposed planes over many acres. This seam is being opened. |
| | | | Main ... .. | 750 | 3 | 4 | 370 | do. | |
| | | | Harvey .. | 1,140 | 3 | 8 | 760 | do. | |
| 17 | Wingate Grange * ... | 356 | Five-quarter ... | 447 | 4 | 1 | 91 | do. | These seams have been extensively worked, and goafed in superposed planes without bringing down any of the water-feeders. |
| | | | Main ... ... | 538 | 5 | 0 | 182 | do. | |
| | | | Low Main .. | 663 | 3 | 2 | 307 | do. | |
| | | | Harvey ... | 923 | 3 | 8 | 567 | do. | |
| 18 | Wylam ... .. | 165 | Yard ... .. | 165 | 3 | 0 | nil. | The Yard coal-seam is lying full of water, under a pressure of 70 pounds per square inch. | There was no increase in the feeders of water due to the workings being under the Yard coal-seam. |
| | | | Brockwell ... | 213 | 3 | 0 | 48 | | |

* Information derived from Mr. T. Bell's "Notes on the Working of Coal-mines under the Sea, and also under the Permian Feeder of Water in the County of Durham," *Transactions of the Manchester Geological Society*, 1899, vol. xxvi., pages 366 to 399, and 554 to 559.

APPENDIX IV.—PARTICULARS OF COAL-SEAMS WORKED UNDER THE WATERS OF OCEANS, RIVERS, LAKES, ETC.

| No. | Name of Colliery. | Name of Coal-seam being worked. | Depth below the Water. | Thickness of Coal-seam. | Water of Ocean, River, Lake, etc. | Remarks. |
|---|---|---|---|---|---|---|
| | *New South Wales.* | | Feet. | Feet. | | |
| 1 | Australian Agricultural Company, Sea Pit or New Winning | Bore-hole | 145 to 190 | 15 to 16 | Pacific Ocean .. | Workings extend about 600 feet beyond high-water mark. The pillars are 96 feet by 36 feet, the bords are 18f eet wide, and the cut-throughs or cross-holings, 9 feet wide. About 4 feet of top coal is left next to the roof. |
| 2 | Hetton ... ... | do. | 300 | 7 to 8 | do. | Workings extend about 500 feet beyond high-water mark. |
| 3 | Do. ... ... | do. | 165 to 300 | 7 to 15 | River Hunter .. | The pillars are made 90 feet by 24 feet; the bords are 18 feet wide, and the cut-throughs or cross-holings, 9 feet wide. |
| 4 | Newcastle Coal-mining Company, A and B Pits | do. | 145 to 170 | 6 to 11 | Pacific Ocean .. | The workings extend about 800 feet beyond high-water mark, including the winnings. About 3 feet of top coal is left next to the roof, and a little bottom coal is also left. |
| 5 | Stockton ... ... | do. | 240 to 260 | 7 to 8 | do. | Workings extend about 2,500 feet beyond high-water mark. The pillars and bords are of the same dimensions as those at the Hetton colliery. |
| 6 | Wickham and Bullock Island | do. | 120 to 260 | 6 to 16 | River Hunter and Throsby Creek | The pillars and bords are of the same dimensions as those at the Hetton colliery. |
| | *Cumberland.* | | | | | |
| 7 | Harrington ... ... | Main Band | 126 to 168 | 6½ | Irish Sea ... | About 2 feet top coal and slate is left on, next to the roof, in narrow places. The minimum thickness of cover has been fixed at 126 feet. The pillars are left 57 feet by 52 feet, the bords are 14 feet wide, and the walls or cross-holings are 9 feet wide. Thus, 32 per cent. of coal is worked, and the pillars are not crushed. About 66 per cent. of the overlying strata is compact sandstone. Feeders of water, occurring in workings where minimum cover had been reached, have since become quite dry. |

| | | | Feet. | Feet. | | |
|---|---|---|---|---|---|---|
| 8 | Workington* ... | — | 90 | 10 | Irish Sea | The workings extend 4,500 feet under the sea. The bords were 15 feet wide and the pillars 21 to 24 feet thick. The manager, in order to increase the output of coal, commenced to rob the pillars, this resulting in falls and feeders of salt-water. Warnings were given as to what would happen, but these were unheeded. On July 30th, 1837, the sea broke in, and 36 men and boys, and a number of horses were drowned, and the colliery irrecoverably destroyed. |
| | *Northumberland.* | | | | | |
| 9 | North Seaton and Cambois | Low Main | 360 | 4 to 6 | German Ocean | At Cambois, bord-and-pillar and longwall is being worked under the sea, and headings are driven 300 feet in advance to ascertain the existence of any fault or break in the strata. |
| | *Durham.* | | | | | |
| 10 | Ryhope† ... ... | Maudlin | 1,830 | 7 | do. | The workings extend 5,500 feet from low-water mark under the ocean, and over 400 acres of goaf have been formed. |
| 11 | Seaham† ... .. | Maudlin | 1,830 | 5 | do. | The workings in the Maudlin seam extend 5,000 feet under the ocean, and about 85 acres of goaf has been formed. |
| | | Hutton | — | 4½ | do. | Twelve pillars, each 120 feet by 90 feet, have been removed in this seam under the goaf of the Maudlin seam, rising seawards 2 to 2½ inches per yard for the last 1,200 feet. |
| 12 | Wearmouth† ... | Maudlin | — | 5½ | do. | Workings extend 4,000 feet under the ocean. |
| | | Hutton | — | 4½ | do. | |
| 13 | Whitburn† ... ... | Maudlin | — | — | — | Workings extend 4,000 feet under the ocean. |

* *A Treatise on the Winning and Working of Collieries*, by Mr. M. Dunn, 1848, page 230.

† Information derived from Mr. Thomas Bell's "Notes on the Working of Coal-mines under the Sea, and also under the Permian Feeder of Water in the County of Durham," *Transactions of the Manchester Geological Society*, 1899, vol. xxvi., pages 366 to 399 and 554 to 559.

APPENDIX IV.—PARTICULARS OF COAL-SEAMS, ETC.—*Continued.*

| No. | Name of Colliery. | Name of Coal seam being worked. | Depth below the Water. | Thickness of Coal-seam. | Water of Ocean, River, Lake, etc. | Remarks. |
|---|---|---|---|---|---|---|
| | | | Feet. | Feet. | | |
| | *Flint.* | | | | | |
| 14 | Point of Ayr ... | Mostyn, 5 Yards | 225 to 309 | 9 | Irish Sea ... | The top coal, 3 feet thick, is left, and 50 per cent. of the lower 6 feet is worked. The pillars are 45 feet by 18 feet, the bords are 15 feet wide, and the thirlings 7½ feet wide. There is no influx of water. |
| | | 3 Yards | 356 to 433 | 6 to 7½ | do. | About 50 per cent. of the lower seams are worked. |
| | | 2 Yards | 499 to 576 | 6 to 7½ | do. | |
| | | Durbog | 607 to 684 | 6 to 7½ | do. | |
| | *Pembrokeshire.* | | | | | |
| 15 | Landshipping* ... | — | — | — | Under a river .. | The bed of the river is composed of sand, 60 feet thick, lying upon rock, and the coal was worked away to within a few feet of the top of this rock. The workings had been stopped but were resumed, when a breach or fissure took place, which inundated the colliery and drowned 40 men and boys in February, 1843. The separation from the waters was so slight that the timbers of the mine arose through the breach. |
| | *Haddingtonshire.* | | | | | |
| 16 | Prestongrange† ... | Great | 360 to 900 | 6½ to 8 | Firth of Forth | The pillars are made 45 feet square and left unworked, and the bords are driven 15 feet wide. |
| | | Jewel | 360 to 900 | 3½ to 4 | do. | |
| | | Beggar | 360 to 900 | 3 | do. | |
| | *Linlithgow.* | | | | | |
| 17 | Bridgeness‡ ... | Six-feet | 320 | 6 | do. | Opened out in 1897. |
| | | Main | 137 to 570 ft. below high-water mark. | 3 to 4½ | do. | Worked on the longwall system. There is 33 feet of brown clay and 5 feet 8 inches of stiff boulder-clay at No. 6 shaft, and it is probably much thicker under the Firth of Forth. |

| | | | Feet. | Feet. | | |
|---|---|---|---|---|---|---|
| | *Spain.* | | | | | |
| 18 | Worked by the Compagnie Royale Asturienne des Mines, Liége§ | — | 130 feet at coastline and 590 feet farther under sea. | 11½ to 40 | Bay of Biscay .. | The seam dips northward under the sea, and the rocks are alternately shales and sandstones, with no mention of clay. The coal is worked to a depth of 100 feet beneath the sea. The entire seam is removed and buildings inserted. Fractures have occurred in the sea-bottom, admitting water in small quantities, and the fissures appear gradually to close again, becoming silted up by the sand of the sea-bottom. |
| | *Cape Breton.* | | | | | |
| 19 | Sydney ... ... | — | 1,000 | 5 | Atlantic Ocean | The workings extend 2,500 feet under the sea. The seam dips under the sea at a rate of 1 in 10. The bords are 17 feet wide, and pillars are left 30 feet by 54 feet. No pillars will be worked until the sea-boundary is reached, but afterwards it is intended to remove the whole of the seam, leaving the goaf to the dip. |
| | *British Columbia.* | | | | | |
| 20 | Nanaimo ... .. | — | 400 to 1,100 | 2 to 12 | Straits of Georgia | The bords are driven 28 feet wide, and the pillars are 60 feet by 39 feet. No pillars are worked, but it is intended to work them at a later date. Superincumbent strata include a considerable thickness of sandstone, and a bed of hard conglomerate; immediately above the seam is a bed of shale; and overlying parts of the sea-bottom is a thickness of silt, which tends to fill all fractures. |
| | *New Zealand.* | | | | | |
| 21 | Taupiri Extended .. | – | 100 to 200 | 20 to 50 | Lake and swampy ground | The overlying strata are of a soft and broken nature. The bords are 14 feet wide, with 24 feet of coal-pillar between, and cross-headings at intervals of 60 to 200 feet. Subsequently, the pillars are split by places driven across at intervals of 33 feet. About 9 feet of top coal is left when working under the lake, and elsewhere 3½ feet is left as a minimum. |

* *A Treatise on the Winning and Working of Collieries*, 1848, by Mr. M. Dunn, page 232. † *Trans. Inst. M.E.*, 1900, vol. xx., page 35.
‡ Mr. H. M. Cadell, *Trans. Inst. M.E.*, 1897, vol. xiv., page 237. § *Trans. Inst. M.E.*, 1897, vol. xii., page 655.

## APPENDIX V. (Fig. 7, Plate XXX.).

*Hetton Colliery.*—July, 1896.—A crush commenced in abandoned workings where the seam, 14 feet thick, had been worked by means of bords driven 18 feet wide and pillars 18 feet thick. The cover overhead was about 230 feet from the top of the Bore-hole coal-seam to the bed of the river Hunter. The area affected was about 4 acres.

*Stockton Colliery.*—1889.—A crush of an area of 11¼ acres near the shafts, extended over the engine-plane and affected the workings in the top and bottom seams, which were separated by the morgan or shale stone, varying from 6 to 12 feet in thickness. In this area, the bords were not less than 24 feet wide, and many of the pillars did not exceed 12 feet in thickness.

July, 1891.—A large area, extending across the engine-plane, was affected, and the working of the mine was stopped for two months. The crush in the bottom seam originated in ground worked by bords 24 feet wide, and pillars 12 feet thick, and spread into an area worked by means of bords 18 feet wide and pillars 18 feet thick. The bottom seam was about 7 feet thick, and the overlying strata were about 350 feet thick. The fracture extended to the surface, as evidenced by buildings being cracked and injured. The crush commenced in old or abandoned workings, and the area affected was about 28¼ acres.

October, 1892.—A crush commenced in a working district in the top seam. The pillars were 18 feet thick and the bords 18 feet wide. The cover overhead was about 270 feet. The coal was very tender, and the inclination of the seam where the crush started was about 1 in 7. The bottom seam had not been worked. The fracture extended to the surface, as shewn by cracks in Fullerton Cove road. The area affected was about 8 acres.

February, 1894.—A crush commenced in abandoned workings, where both top and bottom seams had been worked. The pillars were 12 feet thick and the bords were 24 feet wide. The cover overhead was about 300 feet thick. The fracture extended to the surface, and several houses were damaged. The area affected was about 3 acres.

*Wickham and Bullock Island Colliery.*—August, 1896.—A crush commenced in a working district, and spread into other districts then abandoned. The seam was 15 feet thick, and worked by means of bords 18 feet wide and pillars 18 feet thick. The overlying cover between the seam and the water was about 220 feet. The fracture extended to the surface, and parts of two streets were damaged. The area affected was about 70 acres. The colliery did not work for 4 weeks after the crush took place.

October, 1897.—A crush commenced in an abandoned part of a district and spread into another part then at work. The seam was 15 feet thick, and was worked by means of bords, 18 feet wide, and the pillars were 18 feet thick. Some bords, 18 feet wide, in which the top-band coal, 4 feet thick, had been left, and pillars, 24 feet wide, of more recent formation than those in which the crush started, were damaged before the ground finally settled. The cover between the seam and the water was about 240 feet thick. The area affected was about 12½ acres. The colliery did not work for a few days. This took place under water known as the "Basin," where dredging operations shortly afterwards proved that the bed of the basin had been lowered in places 4 feet and had increased the depth of the water to that extent.

## APPENDIX VI.—Description of the Sinking of the No. 3 Pit, Stockton Colliery.

In the sinking of the Hetton, Wickham and Bullock Island, and Stockton collieries, on account of the sand and other alluvial deposits found near the surface, being unconsolidated and often charged heavily with water, difficulty was experienced in the sinking operations until the solid strata or stone-head was reached, and the shafts made secure by means of cast-iron tubbing, which is put in to the following depths from the surface:—

| Name of Colliery. | Shafts. | Tubbing. Feet. |
|---|---|---|
| Hetton ... ... ... | Downcast ... ... | 181 |
| Do. ... ... ... | Upcast ... ... | 178 |
| Wickham and Bullock Island | Downcast ... ... | 163 |
| Do. do. | Upcast ... ... | 157 |
| Stockton ... ... ... | Downcast ... ... | 80 |
| Do. ... ... ... | Upcast ... ... | 120 |
| Do. ... ... ... | No. 3 ... ... | 281 |

The section of strata sunk through in the No. 3 shaft of the Stockton colliery shows that the alluvial deposit was 208½ feet thick. The strata were no doubt rendered particularly unreliable in consequence of the proximity of a fault, the existence and position of which was only positively determined subsequent to the completion of the shaft.

On October 23rd, 1891, operations were commenced with the full knowledge that difficulties would have to be encountered. In the first place, an excavation was made to a depth of 22 feet, and the sand was lined by the usual method of piling and boarding.

A powerful framework had been erected to serve as a guide to the shaft-cylinder, to ensure as far as possible that it was truly vertical, when it penetrated into the alluvial strata. This framework permitted the erection and adjustment of 6 rings at a time on the surface, equal to a height of 21 feet. Each ring consisted of 8 segments, and the cast-iron was 1¼ inches thick, with ribs, 1⅛ inches wide on the inside of the shaft, which was 10 feet in internal diameter.

The advantages accruing from the preliminary sinking of the pit to a depth of 22 feet were very marked, as greater facility was obtained for building the rings, and a saving of expense was effected and depth gained, by forcing down 6 rings, a length of 21 feet, in one operation, instead of repeating it for each ring, 3½ feet in depth.

The pressure necessary to force down the cylinder was obtained by sand, loaded into bags. The distribution of this weight was accomplished by fixing strong balks of hardwood timber horizontally across the mouth of the shaft, and resting directly on pinewood planking, placed immediately between the underside of the balks and the rim of the cylinder, upon which the soft wood acted as a cushion. The main balks, 14 inches square, were laid in tiers, each tier upward, being increased in length, until the third and topmost one had a length of about 40 feet (Fig. 4, Plate XXIX.).

By this method, the area for weight-distribution was amply secured, and at the same time the strength of the balks was maintained, with at all times an ample margin of safety. The main balks were laid in pairs at the required distance apart, and the top tier was crossed by others at right angles, leaving a square opening at the centre of the shaft, for the free passage of the sinking bucket and other internal operating gear. The main-weight balks were

decked with supplementary balks, and the bags of sand were evenly distributed thereon until the desired weight for the time being was obtained.

Safety-chocks, A (Fig. 4, Plate XXIX.), were constructed at the ends, to prevent the cylinder from slipping downward when the divers were working in the bottom of the pit.

Notwithstanding the care exercised during the operation of sinking the cylinder, it was found, when it had reached a depth of 60 feet, that it had lurched some 18 inches from the perpendicular. The work of re-adjusting the cylinder was performed by securing it, on the lower side, at the periphery, with chains attached to a powerful screw, and this was supplemented by shores kept tightly wedged on the lower side.

In addition, a 400 gallons tank was fixed at the surface on the higher side, with pipes connected thereto, leading down to the bottom of the segments of tubbing. As the water was baled from the shaft, it was discharged into the tank, and being returned direct through the pipes it acted with force sufficient to keep the sand in suspension, materially lessening the resistance to be overcome by the cylinder. This method was highly successful, and in a short time the cylinder was restored to a perpendicular position, and the sinking was continued.

During the process of sinking the cylinder, when the resistance of the strata was sufficient to balance the loading, the method just described was adopted, with the result that the sand was stirred into suspension, and large quantities were readily removed. This caused a downward movement of the sand on the outside of the cylinder, which created sufficient momentum to disturb the equilibrium and thus obtain further sinking of the latter.

At a depth of about 120 feet, strong blue clay was encountered, and its resistance was sufficient to prevent the further sinking of the cylinder by the methods already described. In order to deal with the clay, a spade or chopper was devised by the management and put into successful operation (Figs. 5 and 6, Plate XXIX.). By its means, the clay was cut up and filled into buckets by divers, whose services were engaged. This sinking trepan or chopper was made of bar-iron, wood and boiler-plate, and was fitted with four knives at each end and two in the centre; and as implied by the term "chopper," it was worked percussively. The value of the work performed by the divers at this stage cannot be over-estimated. The thickness of the first layer of clay was about 16 feet, and until this stratum was met with at a depth of 149 feet 8 inches, the volume of water was somewhat excessive, and rose and fell in the shaft at the same time as the tides.

The system pursued, whenever a diver was intended to operate, was to bale out the water by means of a bucket down to a given level, namely, a minimum depth over the diver to start with of not less than 60 feet. The motive for having this head in the shaft was to have an internal pressure, sufficient to counterbalance and resist any liability to an inrush of strata, while the diver was working in the shaft-bottom.

The time occupied by the diver under water varied from 2 to 4 hours, but it was generally limited by the rising of the water in the shaft to a maximum of 110 feet. While he was operating, the safety-chocks, A (Fig. 4, Plate XXIX.), were placed under the weight-bearers to prevent any undue or sudden sinking of the cylinder, resulting from the removal of the clay. It was likewise necessary not to remove too great a quantity, nor too near the edges of the cylinder, until they had been sunk further down, as any upward bursting of the clay would undoubtedly have undone the work already performed.

When the cutting-edge of the cylinder had reached a depth of 135 feet 6 inches, and had just pierced a bed of loamy clay, it was found that the lateral pressure and the adhesiveness of the alternating clay-beds, prevented the cylinder from being forced further downward compatible with the safety of the shaft. It was not considered advisable to increase the weights, which then amounted to about 1,400 tons of loading, and approximately 162 tons 14 cwts. of cylinder. Any injudicious attempt to force the latter further downward by additional weighting, might have seriously fractured the cylinder and resulted in the collapse of the shaft.

Under these circumstances, it was decided that the safe limit of sinking the cylinder, 10 feet in diameter, had been reached, and it was therefore resolved that the shaft should be reduced in diameter. The internal diameter of the cylinder was reduced to 8 feet 10 inches, with six segments to a ring, each 3½ feet in depth, and 1¼ inches thick of cast-iron.

Before inserting the inner cylinder, it was decided to bore in the shaft, in order to ascertain as accurately as possible the nature of the intervening strata before the coal-seam was reached. One bore-hole was put down on the east and one on the west side of the shaft. Four-inches tubes were drifted down from the surface, where the bores were intended to be placed, and the work was carried out by means of ordinary percussion-rods.

As showing the variable nature of the delta-deposits, as proved by the various bore-holes put down on the Stockton peninsula, a noticeable confirmation was established by the two bore-holes, which were put down less than 10 feet apart. The hole on the east side was much harder to bore, owing to the greater density of the strata, and their variable thicknesses. The completion of these bores afforded the desired information. The shaft was then filled to the top with sand, and the work of telescoping commenced.

When the stratum of strong blue clay was penetrated, at a depth of 149 feet, the effect of the tidal waters was entirely removed, and the body of water materially reduced in the shaft. After passing through 16 feet of this clay, and at a depth of 165 feet, a hard agglutinated mass of shingle, 7 feet 8 inches thick, offered, under the conditions, exceptional difficulties. The sizes of the stones forming this bed were very variable, and the consequent unequal resistance to the downward movement of the cylinder rendered it difficult to obtain advancement together with accuracy; but in time this and subsequent beds were passed through, and the cylinder forced from the surface until the cutting-edge reached a depth of 233 feet 9 inches.

The shaft is tubbed to a depth of 281 feet 2 inches, but from 233 feet 9 inches, the rings were inserted by undersetting, with the sinkers in the bottom of the shaft.

The telescoping of the 10 feet tubbing commenced on November 7th, 1893, and reached the bottom at a depth of 135 feet 6 inches on February 9th, 1894. The floor of the bottom seam at a depth of 290 feet 4 inches was reached on June 15th, 1895. The time occupied in sinking this shaft, including all delays, was therefore about 3 years and 8 months.

Connection was made between the then workings of Stockton colliery and the No. 3 shaft on September 20th, 1895. This connection materially improved the ventilation, and also provided another outlet or means of escape in the event of any accident in the winding-shaft. The shaft is fitted with ladders in several stages. The bottom of No. 3 shaft is about 70 feet above the bottom of the winding-shaft. It is situated at a distance of 264 feet from high-water mark.

## APPENDIX VII.—Sections of Strata in Bore-holes and Shafts.

1.—*No. 1 Bore-hole of the Australian Agricultural Company.*—The top of the hole is 6·71 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Blue sandstone ... | 2 | 0 | 2 | 0 |
| 2 | Ironstone ... ... | 0 | 5 | 2 | 5 |
| 3 | Blue sandstone ... | 4 | 0 | 6 | 5 |
| 4 | Ironstone ... ... | 0 | 5 | 6 | 10 |
| 5 | Blue sandstone ... | 5 | 0 | 11 | 10 |
| 6 | Ironstone ... ... | 0 | 6 | 12 | 4 |
| 7 | Blue sandstone ... | 6 | 0 | 18 | 4 |
| 8 | Soft brown *coaly* shale ... ... | 4 | 7 | 22 | 11 |
| 9 | **COAL**, clean ... | 1 | 7 | 24 | 6 |
| 10 | Blue slate, with *coal*-pipings ... ... | 2 | 9 | 27 | 3 |
| 11 | Blue post ... ... | 1 | 1 | 28 | 4 |
| 12 | Blue slate ... ... | 1 | 4 | 29 | 8 |
| 13 | Blue post ... ... | 3 | 2 | 32 | 10 |
| 14 | Blue slate ... ... | 1 | 0 | 33 | 10 |
| 15 | Blue post ... ... | 1 | 0 | 34 | 10 |
| 16 | Blue slate ... ... | 0 | 6 | 35 | 4 |
| 17 | Blue post ... ... | 0 | 7 | 35 | 11 |
| 18 | Blue slate ... ... | 1 | 9 | 37 | 8 |
| 19 | Blue post ... ... | 1 | 3 | 38 | 11 |
| 20 | Blue slate ... ... | 2 | 0 | 40 | 11 |
| 21 | Blue post ... ... | 1 | 8 | 42 | 7 |
| 22 | Blue slate, with threads of ironstone | 5 | 4 | 47 | 11 |
| 23 | Ironstone ... ... | 0 | 10 | 48 | 9 |
| 24 | Blue slate, with hard post girdles | 1 | 3 | 50 | 0 |
| 25 | Blue post ... ... | 5 | 8 | 55 | 8 |
| 26 | Ironstone ... ... | 0 | 9 | 56 | 5 |
| 27 | Blue post ... ... | 0 | 6 | 56 | 11 |
| 28 | Hard blue slate ... | 0 | 6 | 57 | 5 |
| 29 | Ironstone ... ... | 0 | 3 | 57 | 8 |
| 30 | Hard blue slate ... | 2 | 7 | 60 | 3 |
| 31 | Blue post ... ... | 1 | 0 | 61 | 3 |
| 32 | Blue slate, with post girdles ... .. | 3 | 5 | 64 | 8 |
| 33 | Blue post ... ... | 2 | 4 | 67 | 0 |
| 34 | White chert ... | 0 | 6 | 67 | 6 |
| 35 | Grey post ... ... | 1 | 11 | 69 | 5 |
| 36 | Blue post, with threads of ironstone ... ... | 4 | 11 | 74 | 4 |
| 37 | Ironstone ... | 0 | 8 | 75 | 0 |
| 38 | Grey post, with small pebbles ... | 6 | 5 | 81 | 5 |
| 39 | Ironstone ... ... | 0 | 7 | 82 | 0 |
| 40 | Crusty grey post | 3 | 8 | 85 | 8 |
| 41 | Soft grey post ... | 9 | 0 | 94 | 8 |
| 42 | Hard grey post ... | 6 | 9 | 101 | 5 |
| 43 | Grey post and slate girdles ... | 19 | 8 | 121 | 1 |
| 44 | Grey post, with ironstone-ribs ... | 7 | 3 | 128 | 4 |
| 45 | Coarse grey post, with pebbles ... | 12 | 1 | 140 | 5 |
| 46 | Black slate-band ... | 0 | 7 | 141 | 0 |
| 47 | Grey post and slate girdles .. ... | 1 | 2 | 142 | 2 |
| 48 | Shelly post ... | 0 | 5 | 142 | 7 |
| 49 | Blue slate ... | 8 | 9 | 151 | 4 |
| 50 | Soft black dant ... | 2 | 6 | 153 | 10 |
| | *Bore-hole Seam.* | | | | |
| 51 | **COAL**, clean | 0 | 4 | | |
| 52 | Blue clay | 0 | 2 | | |
| 53 | **COAL**, coarse and slaty | 0 | 6 | | |
| 54 | Soft black dant ... | 0 | 7 | | |
| 55 | **COAL**, coarse and slaty | 0 | 4 | | |
| 56 | **COAL**, clean | 0 | 3 | | |
| 57 | Black smut | 0 | 2 | | |
| 58 | **COAL**, clean | 0 | 4 | | |
| 59 | Slate and *coal*-pipes | 0 | 5 | | |
| 60 | Smut ... | 0 | 1 | | |
| 61 | Blue slate | 1 | 4 | | |
| 62 | Clay ... | 0 | 2 | | |
| 63 | **COAL** and bands ... | 14 | 3 | | |
| 64 | **COAL**, splint | 0 | 2 | | |
| | | 19 | 1 | 172 | 11 |
| 65 | Blue slate ... ... | — | | — | |
| 66 | Post ... ... | — | | — | |

2.—*No. 2 Bore-hole, situated near the No 2 or Bore-hole Pit of the Australian Agricultural Company.*—The top of the hole is 13·94 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Sand ... ... | 28 | 0 | 28 | 0 |
| 2 | Slate-coloured clay | 2 | 6 | 30 | 6 |
| 3 | Sand ... ... | 10 | 0 | 40 | 6 |
| 4 | Clay ... .. | 11 | 6 | 52 | 0 |
| 5 | Clay ... ... | 28 | 6 | 80 | 6 |
| 6 | *Coal*-smut, with blue clay-slate and *coal*-pipes ... ... | 15 | 0 | 95 | 6 |
| 7 | Blue slate ... ... | 10 | 3 | 105 | 9 |
| 8 | Chert-bed ... ... | 0 | 1 | 105 | 10 |

APPENDIX VII.—SECTIONS OF STRATA, ETC.—*Continued.*

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 9 | Blue slate and post girdles ... ... | 5 | 6 | 111 | 4 |
| 10 | Post and slate girdles ... ... | 14 | 0 | 125 | 4 |
| 11 | Grey post ... .. | 0 | 5 | 125 | 9 |
| 12 | Post and slate girdles ... ... | 6 | 3 | 132 | 0 |
| 13 | Grey post ... ... | 0 | 10 | 132 | 10 |
| 14 | Post and slate girdles ... ... | 5 | 3 | 138 | 1 |
| 15 | Grey post ... ... | 1 | 10 | 139 | 11 |
| 16 | Post and slate girdles ... ... | 1 | 6 | 141 | 5 |
| 17 | Grey post ... ... | 6 | 6 | 147 | 11 |
| 18 | Blue slate ... ... | 1 | 4 | 149 | 3 |
| 19 | Grey post, shelly ... | 2 | 9 | 152 | 0 |
| 20 | Ironstone ... | 0 | 6 | 152 | 6 |
| 21 | Grey post, shelly ... | 4 | 3 | 156 | 9 |
| 22 | Crusted grey post | 1 | 1 | 157 | 10 |
| 23 | Blue slate ... .. | 2 | 1 | 159 | 11 |
| 24 | Crusted grey post | 2 | 7 | 162 | 6 |
| 25 | Post and slate girdles ... ... | 1 | 4 | 163 | 10 |
| 26 | Post ribbed ironstone ... ... | 1 | 10 | 165 | 8 |
| 27 | Post and slate girdles ... ... | 2 | 3 | 167 | 11 |
| 28 | Conglomerate, sand and pebbles ... | 3 | 10 | 171 | 9 |
| 29 | Blue slate, with several small beds of ironstone, post and chert-rock .. | 6 | 2 | 177 | 11 |
| 30 | Slate-ironstone ... | 4 | 5 | 182 | 4 |
| 31 | *Coal*-smut .. ... | 0 | 7 | 182 | 11 |
| 32 | Slate ... ... | 0 | 5 | 183 | 4 |
| 33 | *Coal*-smut ... ... | 0 | 8 | 184 | 0 |
| | *Bore-hole Seam.* | | | | |
| 34 | **COAL** and bands | 17 | 0 | 201 | 0 |

3.—*No. 13 Bore-hole of the Australian Agricultural Company.*—The top of the hole is 2 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Post ... ... | 34 | 0 | 34 | 0 |
| 2 | Hard band ... | 0 | 1 | 34 | 1 |
| 3 | Soft shale and *coal* | 2 | 3 | 36 | 4 |
| | Ft. In. | | | | |
| 4 | **COAL** ... 1 7 | | | | |
| 5 | Band ... 0 1 | | | | |
| 6 | **COAL** ... 1 11 | | | | |
| | | 3 | 7 | 39 | 11 |
| 7 | Blue slate ... ... | 8 | 2 | 48 | 1 |
| 8 | Slate and post girdles ... ... | 19 | 6 | 67 | 7 |
| 9 | Slate ... ... | 1 | 2 | 68 | 9 |
| 10 | **COAL** ... ... | 1 | 7 | 70 | 4 |
| 11 | Slate ... ... | 3 | 2 | 73 | 6 |
| 12 | Slate and post girdles ... ... | 13 | 8 | 87 | 2 |
| 13 | Post .. ... | 1 | 4 | 88 | 6 |
| 14 | Fire-clay ... ... | 0 | 11 | 89 | 5 |
| 15 | Hard grey post ... | 1 | 0 | 90 | 5 |
| 16 | Hard post ... ... | 4 | 6 | 94 | 11 |
| 17 | Post and slate girdles ... ... | 23 | 8 | 118 | 7 |
| 18 | Very hard post ... | 69 | 6 | 188 | 1 |
| 19 | Hard post ... ... | 13 | 11 | 202 | 0 |
| 20 | Post ... ... | 38 | 3 | 240 | 3 |
| 21 | Slate ... ... | 2 | 9 | 243 | 0 |
| 22 | Slaty *coal*, crusted | 5 | 7 | 248 | 7 |
| 23 | Hard blue brassy stone, like slag ... | 4 | 0 | 252 | 7 |
| | *Bore-hole Seam.* Ft. In. | | | | |
| 24 | **COAL**, black, crusted and slaty 5 7 | | | | |
| 25 | Black slate 2 3 | | | | |
| 26 | **COAL**, crusted and slaty 7 0 | | | | |
| 27 | Black slate and *coal*-bands ... 4 11 | | | | |
| | | 19 | 9 | 272 | 4 |
| 28 | Crusted stone like post ... ... | 1 | 4 | 273 | 8 |
| 29 | Blue post ... ... | 8 | 7 | 282 | 3 |

4.—*No. 14 Bore-hole of the Australian Agricultural Company.*—The top of the hole is 3 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Post ... ... | 16 | 7 | 16 | 7 |
| 2 | Slate and *coal*-pipes | 1 | 1 | 17 | 8 |
| 3 | **COAL** ... ... | 3 | 0 | 20 | 8 |
| 4 | Post and slate girdles .. ... | 33 | 3 | 53 | 11 |
| 5 | **COAL** ... ... | 1 | 8 | 55 | 7 |
| 6 | Slate ... ... | 1 | 11 | 57 | 6 |
| 7 | Post ... ... | 0 | 11 | 58 | 5 |
| 8 | Post and slate girdles ... ... | 11 | 6 | 69 | 11 |

APPENDIX VII.—Sections of Strata, etc.—*Continued.*

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 9 | Very hard post ... | 2 | 3 | 72 | 2 |
| 10 | Post and slate girdles ... ... | 10 | 3 | 82 | 5 |
| 11 | Slate and post girdles ... ... | 14 | 10 | 97 | 3 |
| 12 | Grey post and slate girdles ... ... | 4 | 6 | 101 | 9 |
| 13 | Slate and post girdles ... ... | 12 | 11 | 114 | 8 |
| 14 | Grey post ... ... | 0 | 8 | 115 | 4 |
| 15 | Slate ... ... | 0 | 6 | 115 | 10 |
| 16 | Very hard grey post | 0 | 8 | 116 | 6 |
| 17 | Post and slate girdles ... ... | 12 | 6 | 129 | 0 |
| 18 | Very hard grey post | 10 | 3 | 139 | 3 |
| 19 | Post and slate girdles ... ... | 10 | 5 | 149 | 8 |
| 20 | Grey post ... ... | 7 | 11 | 157 | 7 |
| 21 | Slate ... ... | 1 | 7 | 159 | 2 |
| 22 | Post ... ... | 2 | 3 | 161 | 5 |
| 23 | Grey post ... ... | 18 | 11 | 180 | 4 |
| 24 | Post and slate girdles ... ... | 2 | 6 | 182 | 10 |
| 25 | Very hard grey post | 0 | 10 | 183 | 8 |
| 26 | Post and slate girdles ... ... | 4 | 3 | 187 | 11 |
| 27 | Slate ... ... | 4 | 1 | 192 | 0 |
| 28 | Fire-clay ... ... | 0 | 5 | 192 | 5 |
| | *Bore-hole Seam.* | Ft. | In. | | |
| 29 | **COAL**,slaty | 0 | 10 | | |
| 30 | **COAL** ... | 0 | 6 | | |
| 31 | **COAL**,slaty | 0 | 10 | | |
| 32 | **COAL** ... | 3 | 0 | | |
| 33 | Slate-band | 0 | 1 | | |
| 34 | **COAL** ... | 5 | 11 | | |
| 35 | Band and slaty *coal* | 0 | 7 | | |
| 36 | **COAL** ... | 4 | 1 | | |
| 37 | *Coaly* slate | 2 | 2 | | |
| 38 | **COAL** ... | 3 | 11 | | |
| | | 21 | 11 | 214 | 4 |
| 39 | Slate ... ... | 2 | 8 | 217 | 0 |
| 40 | Post... ... ... | 1 | 0 | 218 | 0 |

5.—*Sea Pit or New Winning of the Australian Agricultural Company.*—The top of the shaft is 77 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Surface, made up ... | 10 | 3 | 10 | 3 |
| 2 | Red loam and clay | 27 | 7 | 37 | 10 |
| 3 | Slate and blue rock ... ... | 20 | 4 | 58 | 2 |
| | | Ft. | In. | | |
| 4 | **COAL** ... | 2 | 4 | | |
| 5 | Clay ... | 0 | 8 | | |
| 6 | **COAL** .. | 2 | 6 | | |
| | | 5 | 6 | 63 | 8 |
| 7 | Blue rock ... ... | 11 | 0 | 74 | 8 |
| 8 | Freestone ... ... | 6 | 0 | 80 | 8 |
| 9 | Hard blue rock ... | 6 | 6 | 87 | 2 |
| 10 | Whinstone ... | 1 | 6 | 88 | 8 |
| 11 | Hard rock ... ... | 7 | 3 | 95 | 11 |
| 12 | Blue rock ... ... | 3 | 0 | 98 | 11 |
| 13 | Soft slate ... ... | 1 | 2 | 100 | 1 |
| 14 | Jerry ... ... | 0 | 6 | 100 | 7 |
| | | Ft. | In. | | |
| 15 | **COAL** ... | 1 | 0 | | |
| 16 | Soft slate | 0 | 2 | | |
| 17 | **COAL** ... | 1 | 4 | | |
| | | 2 | 6 | 103 | 1 |
| 18 | Slate ... ... | 0 | 8 | 103 | 9 |
| 19 | Hard slate ... ... | 4 | 0 | 107 | 9 |
| 20 | Ironstone ... ... | 0 | 2 | 107 | 11 |
| 21 | Freestone ... ... | 4 | 1 | 112 | 0 |
| 22 | Ironstone ... ... | 0 | 1 | 112 | 1 |
| 23 | Freestone ... ... | 6 | 8 | 118 | 9 |
| 24 | Hard rock ... ... | 2 | 2 | 120 | 11 |
| 25 | Black rock... ... | 0 | 2 | 121 | 1 |
| 26 | Freestone ... ... | 3 | 6 | 124 | 7 |
| 27 | Ironstone ... ... | 0 | 2 | 124 | 9 |
| 28 | Black slate ... | 0 | 7 | 125 | 4 |
| 29 | Freestone ... ... | 5 | 6 | 130 | 10 |
| 30 | Ironstone ... ... | 0 | 2 | 131 | 0 |
| 31 | Freestone ... ... | 1 | 3 | 132 | 3 |
| 32 | Black slate ... | 1 | 3 | 133 | 6 |
| 33 | Light slate... ... | 4 | 11 | 138 | 5 |
| | | Ft. | In. | | |
| 34 | **COAL** ... | 1 | 1 | | |
| 35 | Fire-clay | 0 | 1 | | |
| 36 | **COAL** ... | 0 | 10 | | |
| | | 2 | 0 | 140 | 5 |
| 37 | Soft slate ... ... | 1 | 8 | 142 | 1 |
| 38 | Freestone ... ... | 1 | 6 | 143 | 7 |
| 39 | Brittle shale ... | 3 | 2 | 146 | 9 |
| 40 | **COAL** ... ... | 0 | 4 | 147 | 1 |
| 41 | Hard slate... ... | 3 | 6 | 150 | 7 |
| 42 | **COAL** and dirt ... | 0 | 10 | 151 | 5 |
| 43 | Hard slate .. .. | 7 | 6 | 158 | 11 |
| 44 | Freestone ... ... | 0 | 8 | 159 | 7 |
| 45 | Black slate ... | 0 | 1 | 159 | 8 |
| 46 | Freestone ... ... | 0 | 9 | 160 | 5 |
| 47 | Black slate ... | 0 | 1 | 160 | 6 |
| 48 | Freestone ... ... | 1 | 0 | 161 | 6 |
| 49 | Black shale ... | 0 | 1 | 161 | 7 |
| 50 | Freestone ... ... | 0 | 6 | 162 | 1 |
| 51 | Black slate ... | 0 | 1 | 162 | 2 |
| 52 | Freestone ... ... | 0 | 6 | 162 | 8 |
| 53 | Soft slate ... ... | 0 | 2 | 162 | 10 |
| 54 | Freestone ... ... | 0 | 8 | 163 | 6 |
| 55 | Hard black slate .. | 0 | 4 | 163 | 10 |
| 56 | Freestone ... ... | 0 | 8 | 164 | 6 |
| 57 | Black slate ... | 7 | 3 | 171 | 9 |

APPENDIX VII.—SECTIONS OF STRATA, ETC.—*Continued.*

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 58 | Grey rock, with black stripes ... | 14 | 0 | 185 | 9 |
| 59 | Freestone ... ... | 4 | 0 | 189 | 9 |
| 60 | Black slate ... | 13 | 0 | 202 | 9 |
| 61 | Freestone ... ... | 2 | 4 | 205 | 1 |
| 62 | Black slate ... | 3 | 2 | 208 | 3 |
| 63 | Freestone ... ... | 1 | 2 | 209 | 5 |
| 64 | Black slate ... | 7 | 6 | 216 | 11 |
| 65 | Freestone ... ... | 0 | 10 | 217 | 9 |
| 66 | Black slate, with thick stripes ... | 3 | 2 | 220 | 11 |
| 67 | Freestone, with thick stripes ... | 4 | 0 | 224 | 11 |
| 68 | Black shale ... | 1 | 2 | 226 | 1 |
| 69 | Freestone ... ... | 3 | 6 | 229 | 7 |
| 70 | Black shale ... | 0 | 5 | 230 | 0 |
| 71 | Freestone ... ... | 0 | 3 | 230 | 3 |
| 72 | Black slate ... | 0 | 1 | 230 | 4 |
| 73 | Hard ironstone ... | 0 | 2 | 230 | 6 |
| 74 | Black slate, with stripes ... ... | 4 | 0 | 234 | 6 |
| 75 | Freestone ... ... | 1 | 6 | 236 | 0 |
| 76 | Hard dark slate ... | 1 | 8 | 237 | 8 |
| 77 | Freestone ... ... | 1 | 4 | 239 | 0 |
| 78 | Black slate ... | 1 | 0 | 240 | 0 |
| 79 | Freestone ... ... | 0 | 11 | 240 | 11 |
| 80 | Black slate ... | 0 | 11 | 241 | 10 |
| 81 | Freestone ... ... | 0 | 7 | 242 | 5 |
| 82 | Black slate, with white stripes ... | 7 | 0 | 249 | 5 |
| 83 | Black slate ... | 6 | 6 | 255 | 11 |
| 84 | Light slate ... | 0 | 5 | 256 | 4 |
| 85 | Black slate ... | 5 | 0 | 261 | 4 |
| 86 | Black soft slate ... | 3 | 0 | 264 | 4 |
| | *Bore-hole Seam.* | | | | |
| | | Ft. | In. | | |
| 87 | COAL ... | 2 | 0 | | |
| 88 | White slate | 0 | 0½ | | |
| 89 | COAL ... | 0 | 3 | | |
| 90 | Slate ... | 0 | 1½ | | |
| 91 | COAL ... | 0 | 4 | | |
| 92 | Slate ... | 0 | 1 | | |
| 93 | COAL ... | 4 | 0 | | |
| 94 | Slate-band | 0 | 1 | | |
| 95 | COAL ... | 3 | 6 | | |
| 96 | Slate-band | 0 | 1 | | |
| 97 | COAL ... | 1 | 8 | | |
| 98 | Morgan ... | 0 | 6 | | |
| 99 | COAL ... | 1 | 0 | | |
| 100 | Slate-band | 0 | 1 | | |
| 101 | COAL ... | 1 | 1 | | |
| 102 | Jerry ... | 1 | 6 | | |
| 103 | COAL .. | 3 | 0 | | |
| 104 | COAL and shale .. | 1 | 9 | | |
| | | —— | | 21 | 1 | 285 | 5 |
| 105 | Grey post ... ... | 9 | 0 | 294 | 5 |

6.—*Pumping-shaft, Ferndale Colliery.*—The top of the shaft is 10 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Sandy shale ... | 9 | 0 | 9 | 0 |
| 2 | Conglomerate ... | 42 | 9 | 51 | 9 |
| 3 | Brown clay ... | 0 | 9 | 52 | 6 |
| 4 | COAL ... ... | 0 | 4 | 52 | 10 |
| 5 | White shale ... | 0 | 4 | 53 | 2 |
| 6 | Conglomerate .. | 2 | 5 | 55 | 7 |
| 7 | Shaly sandstone ... | 1 | 6 | 57 | 1 |
| 8 | Conglomerate ... | 20 | 6 | 77 | 7 |
| 9 | Clay ... ... | 0 | 6 | 78 | 1 |
| 10 | Conglomerate ... | 20 | 0 | 98 | 1 |
| 11 | Dark shale ... ... | 5 | 3 | 103 | 4 |
| | *Bore-hole Seam.* | | | | |
| | | Ft. | In. | | |
| 12 | COAL ... | 1 | 6 | | |
| 13 | Brown clay | 1 | 10 | | |
| 14 | COAL, soft | 0 | 6 | | |
| 15 | White clay | 0 | 8 | | |
| 16 | COAL ... | 3 | 3 | | |
| | | —— | | 7 | 9 | 111 | 1 |

7.—*Working Shaft, Hetton Colliery, Carrington, adjacent to the Cranes fronting Newcastle Harbour.*—The top of the shaft is 10 feet 5 inches above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Made-up ground ... | 3 | 3 | 3 | 3 |
| 2 | Sand ... ... | 44 | 0 | 47 | 3 |
| 3 | Clay ... ... | 69 | 0 | 116 | 3 |
| 4 | Clay and black sand | 14 | 6 | 130 | 9 |
| 5 | Clay ... ... | 36 | 6 | 167 | 3 |
| 6 | Soft rock ... ... | 5 | 0 | 172 | 3 |
| 7 | Rock ... ... | 45 | 0 | 217 | 3 |
| 8 | Shale ... ... | 1 | 0 | 218 | 3 |
| | *Bore-hole Seam.* | | | | |
| | | Ft. | In. | | |
| 9 | COAL ... | 0 | 3 | | |
| 10 | Band ... | 0 | 1 | | |
| 11 | COAL ... | 0 | 4 | | |
| 12 | Band ... | 0 | 2 | | |
| 13 | COAL ... | 0 | 6 | | |
| 14 | Band ... | 0 | 2 | | |

APPENDIX VII.—SECTIONS OF STRATA, ETC.—*Continued.*

| No. | Description of Strata. | Ft. | In. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|---|---|
| 15 | **COAL** ... | 0 | 10 | | | | |
| 16 | Band ... | 0 | 1 | | | | |
| 17 | **COAL** ... | 2 | 1 | | | | |
| 18 | Band ... | 0 | 1 | | | | |
| 19 | **COAL** ... | 3 | 0 | | | | |
| 20 | Band ... | 0 | 1 | | | | |
| 21 | **COAL** ... | 5 | 0 | | | | |
| 22 | **COAL** and bands... | 1 | 6 | | | | |
| 23 | **COAL** ... | 2 | 0 | | | | |
| 24 | Jerry ... | 1 | 0 | | | | |
| 25 | **COAL** ... | 5 | 0 | | | | |
| | | | | 22 | 2 | 240 | 5 |

8.—*No. 1 Bore-hole with the No. 7 Diamond Drill, Nobbys, Newcastle.*—The top of the hole is 12 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Standpipe ... ... | 15 | 0 | 15 | 0 |
| 2 | Shaly sandstone ... | 15 | 3 | 30 | 3 |
| 3 | Conglomerate ... | 9 | 10 | 40 | 1 |
| 4 | Shaly sandstone ... | 8 | 5 | 48 | 6 |
| 5 | Sandstone and conglomerate ... | 12 | 8 | 61 | 2 |
| 6 | Sandstone ... ... | 6 | 11 | 68 | 1 |
| 7 | Shale and sandstone, with ironstone-bands ... ... | 14 | 11 | 83 | 0 |
| 8 | Shale and clay ... | 0 | 3 | 83 | 3 |
| | Ft. In. | | | | |
| 9 | **COAL** with bands .. 1 2 | | | | |
| 10 | **COAL** ... 1 7 | | | | |
| 11 | Clay-band 0 2 | | | | |
| 12 | **COAL** ... 1 11 | | | | |
| | —— | 4 | 10 | 88 | 1 |
| 13 | Shale ... ... | 1 | 6 | 89 | 7 |
| 14 | Shale and sandstone | 30 | 11 | 120 | 6 |
| 15 | Shale ... ... | 3 | 9 | 124 | 3 |
| | Ft. In. | | | | |
| 16 | **COAL** ... 1 2 | | | | |
| 17 | Clay-bands 0 1 | | | | |
| 18 | **COAL** ... 1 0 | | | | |
| 19 | **COAL** & bands ... 0 5 | | | | |
| | —— | 2 | 8 | 126 | 11 |
| 20 | Shale ... ... | 1 | 10 | 128 | 9 |
| 21 | Shale and sandstone | 52 | 10 | 181 | 7 |
| 22 | Sandstone ... ... | 25 | 5 | 207 | 0 |
| 23 | Sandstone and shale | 72 | 9 | 279 | 9 |
| 24 | Shale, with ironstone-bands ... | 5 | 5 | 285 | 2 |
| | *Bore-hole Coal-seam.* Ft. In. | | | | |
| 25 | **COAL**, burnt 1 5 | | | | |
| 26 | Shale ... 0 2 | | | | |
| 27 | **COAL**, burnt 1 11 | | | | |
| 28 | Clay and burnt *coal*-bands 2 7 | | | | |
| 29 | Dolerite ... 5 10 | | | | |
| 30 | **COAL**, burnt 0 11 | | | | |
| 31 | Clay ... 0 3 | | | | |
| 32 | **COAL**, burnt 1 7 | | | | |
| 33 | Black shale 4 11 | | | | |
| 34 | **COAL**, burnt 0 7 | | | | |
| 35 | Clay ... 1 3 | | | | |
| 36 | **COAL**, burnt 3 11 | | | | |
| 37 | **COAL**, good 2 8 | | | | |
| 38 | **COAL** and jerry-bands 0 4 | | | | |
| | —— | 28 | 4 | 313 | 6 |
| 39 | Sandstone ... ... | 10 | 9 | 324 | 3 |

9.—*A Pit of the Newcastle Coal-mining Company.*—The top of the shaft is 100 feet 6 inches above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Strong Clay ... | 15 | 0 | 15 | 0 |
| 2 | **COAL**, crop ... | 3 | 0 | 18 | 0 |
| 3 | Blue clay, clod ... | 9 | 0 | 27 | 0 |
| 4 | Sandstone-bed, with "bowlers" ... | 3 | 0 | 30 | 0 |
| 5 | Blue metal ... ... | 10 | 0 | 40 | 0 |
| 6 | Grey sandstone-rock, in close beds ... ... | 25 | 0 | 65 | 0 |
| 7 | Blue metal, in beds | 7 | 0 | 72 | 0 |
| 8 | Strong hard metal, with *coal*-pipes ... | 10 | 0 | 82 | 0 |
| 9 | Ironstone ... ... | 0 | 6 | 82 | 6 |
| | *Dirty Seam.* Ft. In. | | | | |
| 10 | **COAL**, good 1 2 | | | | |
| 11 | Strong fire-clay ... 0 9 | | | | |
| 12 | **COAL**, good 1 6 | | | | |
| 13 | Soft brown fire-clay ... 0 4 | | | | |
| 14 | **COAL**, good 1 8 | | | | |
| 15 | **COAL**, with thin layers of dirt intermixed ... 2 8 | | | | |
| | —— | 8 | 1 | 90 | 7 |

APPENDIX VII.—SECTIONS OF STRATA, ETC.—*Continued.*

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 16 | Strong blue metal... | 6 | 0 | 96 | 7 |
| 17 | Very strong hard close-grained grey sandstone, no bedding ... ... | 28 | 0 | 124 | 7 |
| 18 | Ironstone ... ... | 0 | 5 | 125 | 0 |
| 19 | Blue metal, with grey post, intermixed with stains of ironstone and balls of ironstone | 16 | 0 | 141 | 0 |
| 20 | **COAL**, good ... | 1 | 0 | 142 | 0 |
| 21 | Strong fire-clay, with balls of ironstone and petrified wood | 7 | 0 | 149 | 0 |
| | *F Pit Seam.* | | | | |
| 22 | **COAL**, good ... | 2 | 0 | 151 | 0 |
| 23 | Blue metal... ... | 4 | 0 | 155 | 0 |
| 24 | Grey post, with a number of beds and facings ... ... | 15 | 0 | 170 | 0 |
| 25 | **COAL**, coarse rough, with three small clay-pipes ... ... | 2 | 6 | 172 | 6 |
| 26 | Grey conglomerate-rock, with pebbles and *coal*-pipes ... | 31 | 0 | 203 | 6 |
| 27 | Blue metal, with stains of ironstone, very strong rock and post girdles without beds ... | 74 | 0 | 277 | 6 |
| | *Bore-hole Seam.* | | | | |
| 28 | **COAL** ... ... | 13 | 0 | 290 | 6 |

10.—*B Pit of the Newcastle Coal-mining Company.*—The top of the pit is 41 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Made-up ground ... | 4 | 2 | 4 | 2 |
| 2 | Hard yellow clay ... | 30 | 0 | 34 | 2 |
| 3 | Yellow clay, with a little sand-mixture | 10 | 0 | 44 | 2 |
| 4 | Soft clay, with boulders ... ... | 31 | 6 | 75 | 8 |
| 5 | **COAL**, very soft... | 1 | 6 | 77 | 2 |
| 6 | Soft blue shale ... | 11 | 0 | 88 | 2 |
| 7 | Soft blue shale ... | 36 | 5 | 124 | 7 |
| 8 | Hard grey post ... | 24 | 1 | 148 | 8 |
| 9 | Blue shale ... ... | 1 | 6 | 150 | 2 |
| 10 | Hard grey post ... | 3 | 6 | 153 | 8 |
| 11 | Blue shale .. ... | 5 | 8 | 159 | 4 |
| 12 | Hard grey post ... | 0 | 10 | 160 | 2 |
| 13 | Blue metal, rather soft ... ... | 7 | 6 | 167 | 8 |
| 14 | Grey post ... ... | 6 | 5 | 174 | 1 |
| 15 | Blue metal... ... | 4 | 7 | 178 | 8 |
| 16 | Dark blue metal, mixed with sandstone-bands ... | 1 | 1 | 179 | 9 |

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| | *Bore-hole Seam.* | | | | |
| 17 | **COAL** ... | 1 | 3 | | |
| 18 | Dark blue shale ... | 1 | 1 | | |
| 19 | **COAL**, top band ... | 2 | 10 | | |
| 20 | **COAL**, big tops ... | 2 | 8½ | | |
| 21 | Bands ... | 0 | 1 | | |
| 22 | **COAL**, bottom lifts ... | 1 | 3 | | |
| 23 | Morgan ... | 0 | 6 | | |
| 24 | **COAL** ... | 0 | 10 | | |
| 25 | Band ... | 0 | 0½ | | |
| 26 | **COAL**, little tops ... | 0 | 10 | | |
| 27 | Jerry ... | 1 | 3 | | |
| 28 | **COAL**, bottom ... | 2 | 3 | | |
| | | | | 14 | 11 |
| | | | | 194 | 8 |

11.—*Harper's Shaft, Port Waratah Colliery.*—The top of the shaft is 10 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft | In. |
|---|---|---|---|---|---|
| 1 | Sandstone ... ... | 50 | 0 | 50 | 0 |
| 2 | Conglomerate ... | 55 | 6 | 105 | 6 |
| 3 | Shale ... ... | 4 | 8 | 110 | 2 |
| | *Bore-hole Seam.* | | | | |
| 4 | **COAL**, roof | 1 | 0 | | |
| 5 | **COAL** ... | 1 | 5 | | |
| 6 | Jerry ... | 0 | 5 | | |
| 7 | **COAL** ... | 4 | 0 | | |
| | | | | 6 | 10 |
| | | | | 117 | 0 |

## APPENDIX VII.—Sections of Strata, etc.—*Continued.*

12.—*No. 1 or Working Shaft, Stockton Colliery.*—The top of the shaft is 13 feet 6 inches above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Sand ... .. | 60 | 0 | 60 | 0 |
| 2 | Sand and Clay ... | 2 | 0 | 62 | 0 |
| 3 | Blue sand ... ... | 4 | 0 | 66 | 0 |
| 4 | Red conglomerate... | 24 | 0 | 90 | 0 |
| 5 | Grey conglomerate | 28 | 0 | 118 | 0 |
| 6 | Fire-clay and blue shale mixed ... | 10 | 9 | 128 | 9 |
| | Ft. In. | | | | |
| 7 | **COAL** ... 2 3 | | | | |
| 8 | Band ... 0 3 | | | | |
| 9 | **COAL** ... 2 3 | | | | |
| | | 4 | 9 | 133 | 6 |
| 10 | Sandstone and blue freestone ... ... | 49 | 0 | 182 | 6 |
| 11 | **COAL**, clean ... | 2 | 0 | 184 | 6 |
| 12 | Freestone ... ... | 130 | 6 | 315 | 0 |
| 13 | Blue shale ... ... | 17 | 0 | 332 | 0 |
| | *Bore-hole Seam.* | | | | |
| | Ft. In. | | | | |
| 14 | **COAL**, clean 2 6 | | | | |
| 15 | Bands, with *coal* ... 1 0 | | | | |
| 16 | **COAL**, clean 14 0 | | | | |
| 17 | Band ... 4 0 | | | | |
| 18 | **COAL**, clean 2 0 | | | | |
| | | 23 | 6 | 355 | 6 |
| 19 | Black shale ... | 7 | 0 | 362 | 6 |
| 20 | Hard freestone ... | 5 | 0 | 367 | 6 |

13.—*No. 3 Shaft, Stockton Colliery.*—The top of the shaft is 22 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | Alluvial deposits ... | 119 | 4 | 119 | 4 |
| 2 | Strong blue clay ... | 4 | 6 | 123 | 10 |
| 3 | Sand ... ... | 1 | 6 | 125 | 4 |
| 4 | Clay... ... ... | 3 | 6 | 128 | 10 |
| 5 | Sand ... ... | 1 | 5 | 130 | 3 |
| 6 | Clay... ... ... | 3 | 0 | 133 | 3 |
| 7 | Sand ... ... | 1 | 0 | 134 | 3 |
| 8 | Loamy clay, with fossils ... ... | 5 | 0 | 139 | 3 |
| 9 | Sand ... .. | 1 | 4 | 140 | 7 |
| 10 | Soft conglomerate... | 1 | 6 | 142 | 1 |
| 11 | Gravel-wash ... | 6 | 11 | 149 | 0 |
| 12 | Strong blue clay ... | 16 | 0 | 165 | 0 |
| 13 | Very hard shingle... | 7 | 8 | 172 | 8 |
| 14 | Soft clay ... ... | 5 | 2 | 177 | 10 |
| 15 | Strong blue clay ... | 1 | 6 | 179 | 4 |
| 16 | Dark clay, mixed with sand... ... | 3 | 11 | 183 | 3 |
| 17 | Conglomerate ... | 0 | 8 | 183 | 11 |
| 18 | Dark clay and sand | 3 | 3 | 187 | 2 |
| 19 | Soft conglomerate... | 0 | 8 | 187 | 10 |
| 20 | Dark sandy clay ... | 3 | 11 | 191 | 9 |
| 21 | Blue clay and pebbles ... ... | 3 | 11 | 195 | 8 |
| 22 | Gravel-wash ... | 12 | 2 | 207 | 10 |
| 23 | Tender post ... | 14 | 8 | 222 | 6 |
| 24 | Smudge-vein ... | 0 | 6 | 223 | 0 |
| 25 | Rotten post ... | 13 | 5 | 236 | 5 |
| 26 | Soft shale ... ... | 16 | 11 | 253 | 4 |
| 27 | Smudge-*coal* .. | 0 | 3 | 253 | 7 |
| 28 | Soft shale ... ... | 2 | 9 | 256 | 4 |
| 29 | Hard band ... .. | 0 | 2 | 256 | 6 |
| | *Bore-hole Seam.* | | | | |
| | Ft. In. | | | | |
| 30 | **COAL** ... 1 4 | | | | |
| 31 | Hard shale 0 2 | | | | |
| 32 | **COAL** and bands ... 2 0 | | | | |
| 33 | **COAL** ... 9 0 | | | | |
| 34 | Dark shale 11 6 | | | | |
| 35 | **COAL** ... 9 10 | | | | |
| | | 33 | 10 | 290 | 4 |
| 36 | Hard grey post ... | 3 | 2 | 293 | 6 |

14.—*Working Shaft, Wickham and Bullock Island Colliery, Carrington.*—The top of the shaft is 12·45 feet above high-water mark.

| No. | Description of Strata. | Thickness of Strata. Ft. | In. | Depth from Surface. Ft. | In. |
|---|---|---|---|---|---|
| 1 | White sand and shells ... ... | 48 | 0 | 48 | 0 |
| 2 | Hard blue clay ... | 9 | 0 | 57 | 0 |
| 3 | Oyster shell-bed ... | 2 | 0 | 59 | 0 |
| 4 | Sandstone, soft grey | 2 | 0 | 61 | 0 |
| 5 | Brown and black clay ... ... | 38 | 0 | 99 | 0 |
| 6 | Sand and gravel ... | 1 | 0 | 100 | 0 |
| 7 | Strong brown clay | 4 | 0 | 104 | 0 |
| 8 | Sand and gravel ... | 15 | 0 | 119 | 0 |
| 9 | White and yellow clay ... ... | 26 | 0 | 145 | 0 |
| 10 | Boulders and clay... | 6 | 0 | 151 | 0 |
| 11 | Rock ... ... | 45 | 0 | 196 | 0 |
| | *Bore-hole Seam.* | | | | |
| 12 | **COAL** and bands | 18 | 6 | 214 | 6 |

ENDIX VIII.—Sections of Bore-hole Coal-seam. The positions of ese sections are indicated by the same numbers on Fig. 7, Plate XXX.

CKTON COLLIERY.

(1.)

| | Ft. | In. |
|---|---|---|
| AL ... | 3 | 4 |
| d ... | 0 | 1 |
| AL ... | 3 | 2 |
| d ... | 0 | 1 |
| AL ... | 1 | 6 |
| | 8 | 2 |

(2.)
Top Seam.

| | Ft. | In. |
|---|---|---|
| AL ... | 4 | 3 |
| d ... | 0 | 1 |
| AL ... | 3 | 3 |
| d ... | 0 | 1 |
| AL ... | 2 | 4 |
| | 10 | 0 |

Bottom Seam.

| | Ft. | In. |
|---|---|---|
| AL ... | 4 | 4 |
| d ... | 0 | 1 |
| AL ... | 3 | 3 |
| d ... | 0 | 1 |
| AL ... | 1 | 9 |
| | 9 | 6 |

(3.)
Top Seam.

| | Ft. | In. |
|---|---|---|
| AL .. | 4 | 3 |
| d ... | 0 | 1 |
| AL ... | 4 | 4 |
| d ... | 0 | 1 |
| AL ... | 2 | 9 |
| | 11 | 6 |

Bottom Seam.

| | Ft. | In. |
|---|---|---|
| AL ... | 3 | 8 |
| d ... | 0 | 1 |
| AL ... | 4 | 0 |
| d ... | 0 | 1 |
| AL ... | 2 | 0 |
| | 9 | 10 |

(4.)

| | Ft. | In. |
|---|---|---|
| AL ... | 2 | 0 |
| d ... | 0 | 2 |
| AL ... | 3 | 3 |
| d ... | 0 | 2 |
| AL ... | 1 | 4 |
| | 6 | 11 |

(5.)

| | Ft. | In. |
|---|---|---|
| AL ... | 2 | 2 |
| ting ... | | — |
| AL ... | 4 | 5 |
| | 6 | 7 |

(6.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 1 | 10 |
| Band ... | 0 | 2 |
| COAL ... | 5 | 4 |
| | 7 | 4 |

WICKHAM AND BULLOCK ISLAND COLLIERY.

(7.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 2 | 8 |
| Morgan ... | 8 | 0 |
| COAL ... | 0 | 7 |
| Jerry ... | 2 | 9 |
| COAL ... | 3 | 10 |
| | 17 | 10 |

(8.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 3 | 0 |
| Band ... | 0 | 1 |
| COAL ... | 1 | 10 |
| Morgan ... | 0 | 6 |
| Refuse *coal* ... | 1 | 4 |
| Band ... | 0 | 1 |
| | 6 | 10 |

(9.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 3 | 8½ |
| Band ... | 0 | 1 |
| COAL ... | 1 | 11 |
| | 5 | 8½ |

(10.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 1 | 3 |
| Jerry ... | 0 | 11 |
| COAL ... | 3 | 4 |
| | 5 | 6 |

HETTON COLLIERY.

(11.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 3 | 5 |
| Band ... | 0 | 1 |
| COAL ... | 1 | 5 |
| | 4 | 11 |

(12.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 3 | 5½ |
| Band ... | 0 | 1 |
| COAL ... | 1 | 2 |
| Morgan ... | 3 | 1 |
| COAL ... | 0 | 7 |
| Band ... | 0 | 0½ |
| COAL ... | 1 | 4 |
| Jerry ... | 0 | 7 |
| COAL ... | 3 | 11 |
| | 14 | 3 |

(13.)

| | Ft. | In. |
|---|---|---|
| COAL and band | 3 | 8 |
| COAL ... | 3 | 5 |
| Band ... ... | 0 | 0½ |
| COAL ... | 3 | 3 |
| Band ... ... | 0 | 3¼ |
| COAL ... | 1 | 4 |
| Morgan ... | 2 | 5 |
| COAL ... | 0 | 6 |
| Band ... ... | 0 | 0½ |
| COAL ... | 1 | 6 |
| Jerry ... ... | 0 | 7 |
| COAL .. | 3 | 9 |
| | 20 | 9¼ |

(14.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 0 | 3 |
| Band ... .. | 0 | 1 |
| COAL ... | 0 | 4 |
| Band ... ... | 0 | 2 |
| COAL ... | 0 | 6 |
| Band ... ... | 0 | 2 |
| COAL ... | 0 | 10 |
| Band ... ... | 0 | 1 |
| COAL ... | 2 | 1 |
| Band ... ... | 0 | 1 |
| COAL ... | 3 | 0 |
| Band ... ... | 0 | 1 |
| COAL ... | 5 | 0 |
| Morgan ... | 1 | 6 |
| COAL ... | 2 | 0 |
| Jerry ... ... | 1 | 0 |
| COAL ... | 5 | 0 |
| | 22 | 2 |

AUSTRALIAN AGRICULTURAL COMPANY.

(15.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 4 | 1 |
| Stone band ... | 0 | 1 |
| COAL, top lift | 3 | 10 |
| Stone band ... | 0 | 1 |
| COAL, bottom lift ... ... | 2 | 0 |
| Morgan ... | 0 | 8 |
| COAL, four inches ... | 0 | 10 |
| Stone band ... | 0 | 1 |
| COAL, little tops | 1 | 0 |
| Jerry ... ... | 2 | 0 |
| COAL, bottom | 3 | 0 |
| | 17 | 8 |

(16.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 3 | 6 |
| Stone band ... | 0 | 1 |
| COAL, top lift | 3 | 0 |
| Stone band .. | 0 | 1 |

APPENDIX VIII.—SECTIONS OF BORE-HOLE COAL-SEAM.—*Continued.*

| | Ft. | In. |
|---|---|---|
| COAL, bottom lift ... ... | 1 | 8 |
| Morgan ... | 0 | 9 |
| COAL, four inches ... | 0 | 9 |
| Stone band ... | 0 | 1 |
| COAL, little tops | 0 | 9 |
| Jerry ... ... | 1 | 10 |
| COAL, bottom | 3 | 0 |
| | 15 | 6 |

(17.)

| | Ft. | In. |
|---|---|---|
| COAL ... | 2 | 0 |
| White slate ... | 0 | 0½ |
| COAL ... | 0 | 3 |
| Slate ... ... | 0 | 1½ |
| COAL ... | 0 | 4 |
| Slate ... ... | 0 | 1 |
| COAL ... | 4 | 0 |
| Slate band ... | 0 | 1 |
| COAL ... | 3 | 6 |

| | Ft. | In. |
|---|---|---|
| Slate band ... ... | 0 | 1 |
| COAL ... | 1 | 8 |
| Morgan ... | 0 | 6 |
| COAL ... | 1 | 0 |
| Slate band ... | 0 | 1 |
| COAL ... | 1 | 1 |
| Jerry ... | 1 | 6 |
| COAL ... | 3 | 0 |
| COAL and shale | 1 | 9 |
| | 21 | 1 |

NEWCASTLE COAL-MINING COMPANY.

(18.)

| | Ft. | In. |
|---|---|---|
| COAL, coarse | 0 | 6 |
| Dark clay ... | 0 | 6 |
| COAL, coarse | 0 | 6 |
| Blue shale ... | 1 | 0 |
| COAL ... | 0 | 8 |
| Blue shale ... | 1 | 6 |
| COAL ... | 2 | 10 |

| | Ft. | In |
|---|---|---|
| Stone band ... | 0 | 1 |
| COAL ... | 2 | 10 |
| Stone band ... | 0 | 1 |
| COAL ... | 1 | 2 |
| Morgan ... | 0 | 10 |
| COAL ... | 0 | 8 |
| Stone and band | 0 | 1 |
| COAL ... | 0 | 7 |
| Jerry .. ... | 1 | 6 |
| COAL, good ... | 0 | 9 |
| COAL, coarse | 1 | 7 |
| | 17 | 8 |

HARPER'S SHAFT.

(19.)

| | Ft. | In. |
|---|---|---|
| COAL, roof ... | 1 | 0 |
| COAL ... | 1 | 5 |
| Jerry ... ... | 0 | 5 |
| COAL ... | 4 | 0 |
| | 6 | 10 |

Mr. THOMAS BELL (Scarborough) wrote that there did not appear to be so great a depth of strata between the working seam and the bed of the river and sea as there was in the north of England, and the seam was thicker in New South Wales. He thought that the bords were driven too wide, and if driven narrower they would not be so liable to break down; thus if the bords were driven, say, 12 feet wide, the pillars might be left proportionately less in width, and if a stone pillar were built at intervals along the middle of the bords it would steady the roof.

Mr. R. W. MOORE (Whitehaven) wrote that he did not notice in Appendix IV., wherein Mr. Atkinson gives particulars of coal-seams worked under oceans, rivers and lakes in Great Britain and other countries, any reference to the Whitehaven collieries, which extended to a greater distance underneath the sea than any others in the world. The farthest workings seaward in those collieries had been made from the William pit in the Main band, where a distance of 19,000 feet from high-water mark had been reached underneath the Irish Sea. The cover, at that extreme point, is about 1,200 feet thick; but, farther out-bye it is much less, by reason of upthrow faults. The Main band, 10 feet thick, is worked on the bord-and-pillar system: the pillars being 75 feet square, and the workings 18 feet wide. The pillars,

## BORING MACHINE.

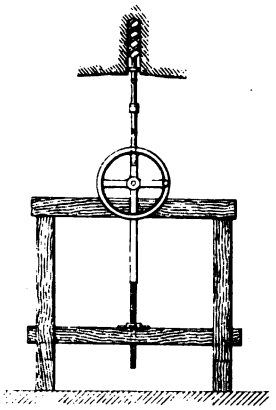


FIG. 2.—SIDE VIEW.

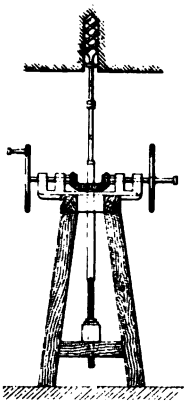
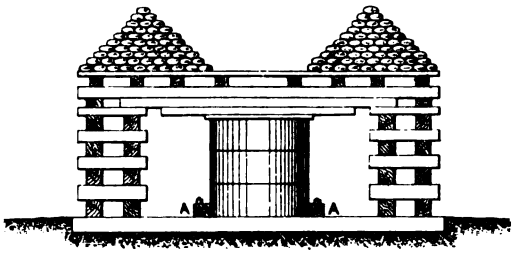


FIG. 3.—END VIEW.

*Scale, 4 Feet to 1 Inch.*




...4.—METHOD OF FORCING-DOWN CYLINDERS.

*Scale, 21 Feet to 1 Inch.*

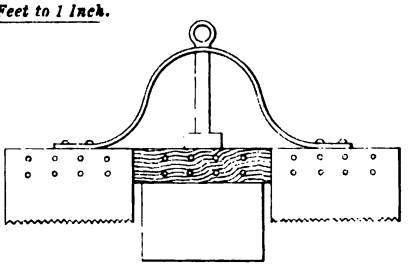


FIG. 5.—SIDE ELEVATION.

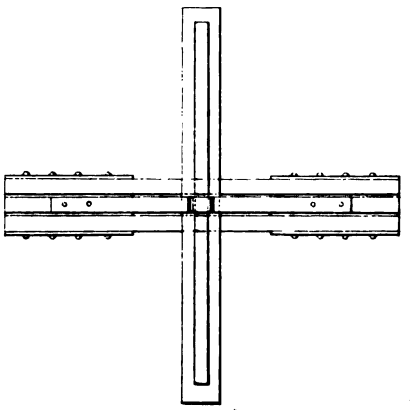
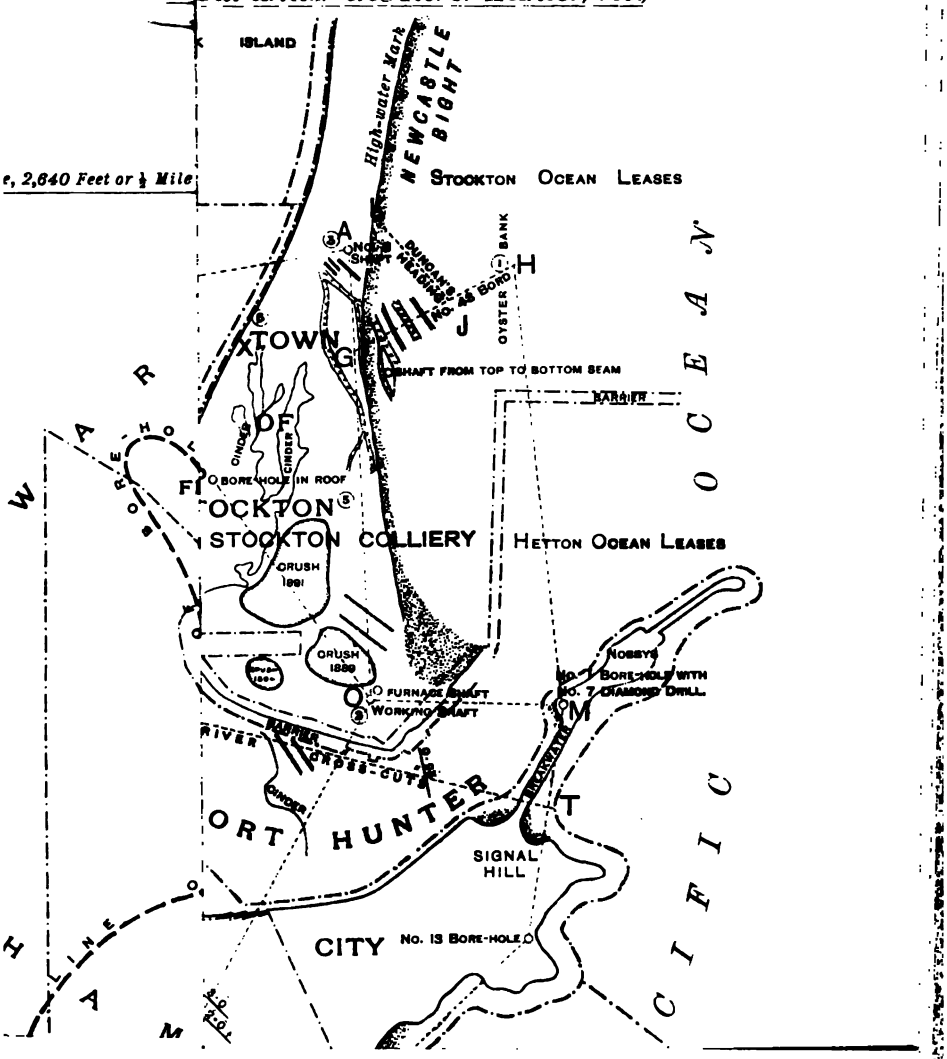
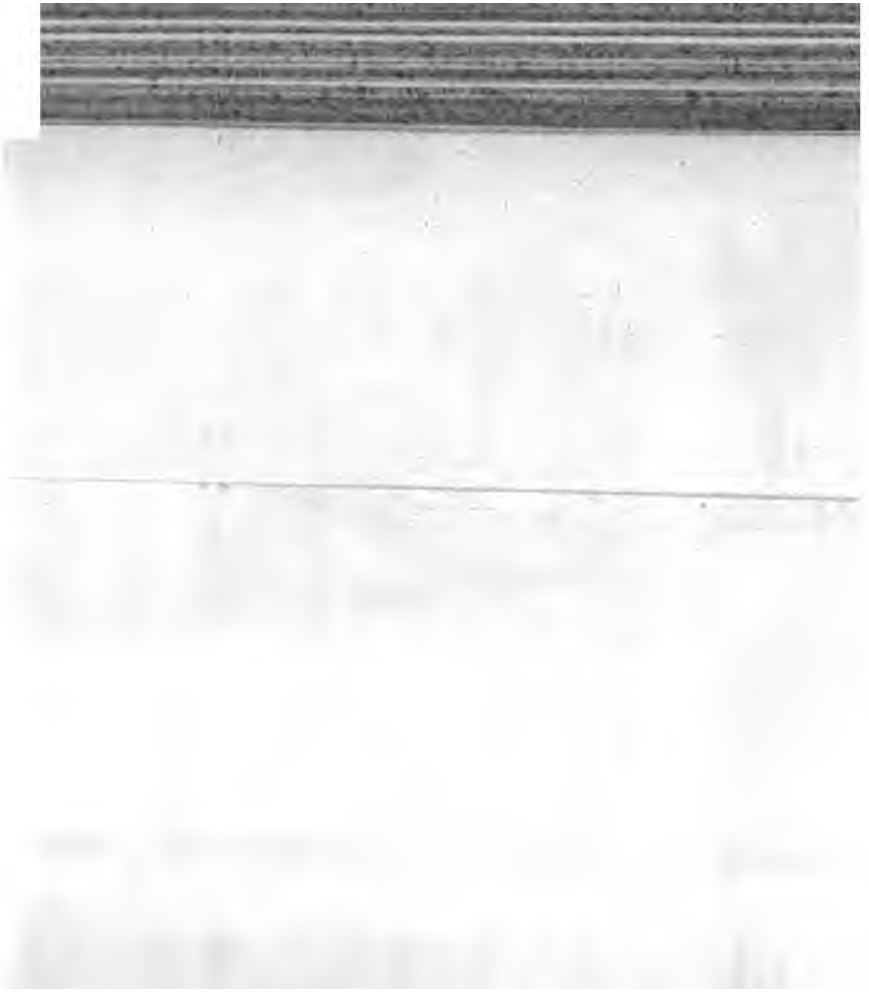


FIG. 6.—PLAN.

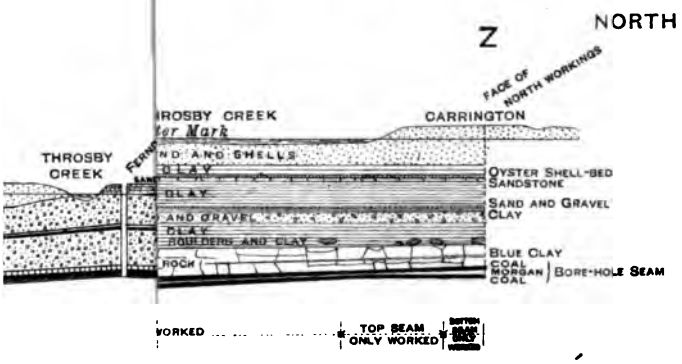
*Scale, 4 Feet to 1 Inch.*

*To Coal under the River Hunter," etc.,*

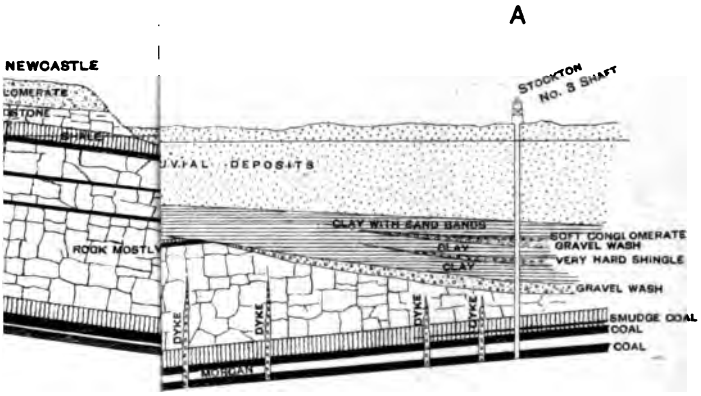




IPANY'S ON LINE Y Z OF FIGS. 1 AND 7,
LLOCK ISLAND COLLIERY WORKING-SHAFT
E OF NORTH WORKINGS.




FROM NEWC
3 SHAFT.

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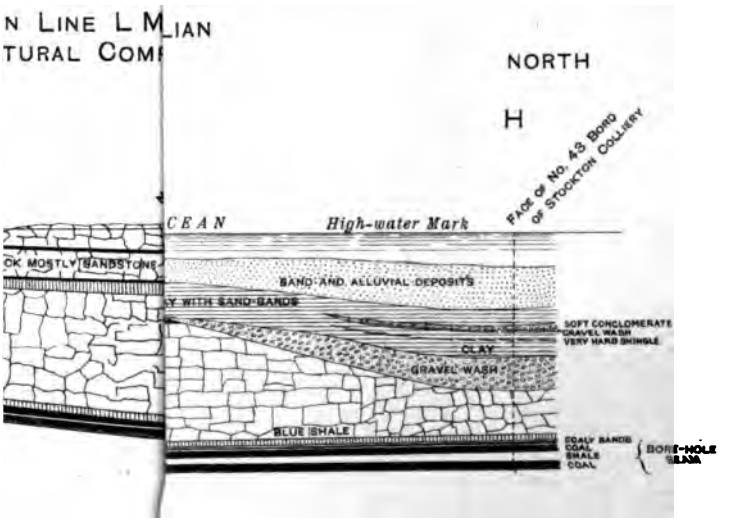
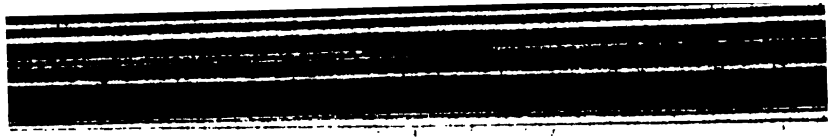
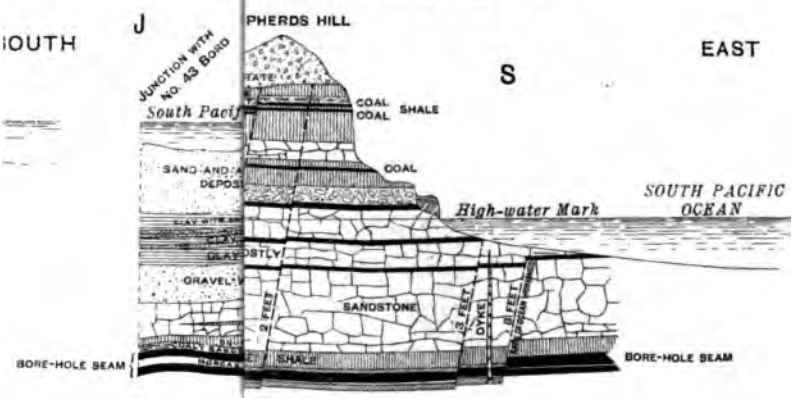
TURAL COM

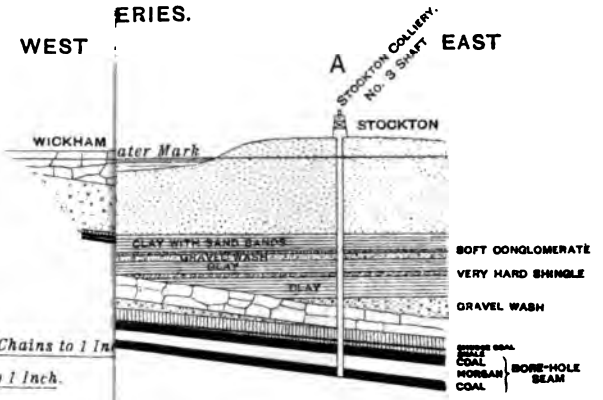




—SECTION ON LIN N LINE R S OF FIGS. I AND 7,
ONG DUNCAN'S HE RICULTURAL COMPANY'S SEA PIT
COLLIERY TO W HEIR OCEAN WORKINGS.



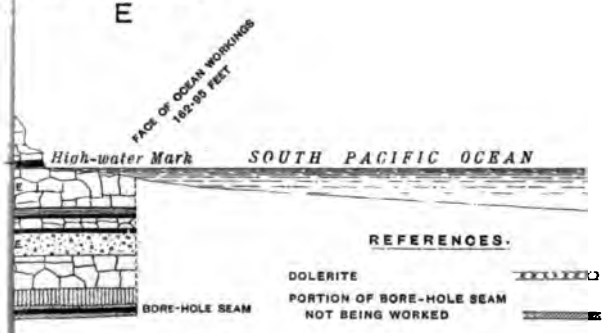

I AND 7,
ARATAH,
ERIES.




*384 Feet or 24 Chains to 1 In*
*ale. 240 Feet to 1 Inch.*

E C E OF FIGS. I AND 7,
NING COMPANY'S A PIT TO
EAN WORKINGS.

EAST




*CEAN*

in one particular district, were robbed many years ago, at a depth of only 360 feet below the bed of the sea; but that was an exceptional case. The Bannock band which occurs about 120 feet above the Main band, and is about 7 feet thick, has also been worked underneath the sea from the same pit, but not to the like extent or at a higher level than the Main band.

Mr. H. M. CADELL (Bo'ness) wrote that he was only sorry that we had not such fine seams of coal under the sea nearer our own shores. He thought that, under the circumstances, 150 feet of cover between the coal and the sea-bed was little enough to leave, especially when there was no certainty of the occurrence of a thick impervious clay-bed on the top of the rock, when covered by the ocean. Mr. Atkinson did not state how far seaward the workings had been carried, nor what was the greatest depth of the submarine developments. Little was said also about fire-damp, which, as there was no escape above, must, if present, be provided for adequately when the area of the submarine workings became extensive.

It was essential to provide ample pillars for the safety of the mines, but on the other hand it was deplorable to have to waste so much good coal. In the circumstances, how would it do to experiment on the removal of the pillars, on principles similar to those that were being found successful in some parts of the thick anthracite coal-fields in Pennsylvania? When he visited that district in 1891, the pillars of the Mammoth seam, which is some 50 feet thick in places, had been worked recklessly under Shenandoah city, leaving a vast room, no less than 300 feet broad and 700 feet long, spanned by an arch of very strong rock, 60 feet thick, at a depth of some 400 feet below the surface.* This prodigious cavity under the town was filled by running down coal-dust and water through a series of 8 inches bore-holes drilled through the roof at different places, the coal-dust or smudge being brought by conveyors from the waste-heaps of old collieries in the vicinity. Referring to the Hunter river workings, the author stated that the shaft was filled with sand when the second and smaller cylinder was put in, which showed that sand must be plentiful in the locality. If this assumption were correct, how would it do to run a thick stream of sand (with enough water to move it) into

* *Trans. M. Inst. of Scotland*, 1891, vol. xiii., page 258.

the old rooms until they were filled to the roof, and pump out the superfluous water afterwards: then, as the Americans did when they had supported the roof of the Mammoth seam with the coal-dust, start to remove the pillars, and let the roof subside gradually on to the sandy filling? Of course, the success of any such plan would depend on whether the coal were sufficiently valuable to remove in this way, and whether the sand could be cheaply got and conveyed to its destination underground. In the case of submarine workings, great empty cavities, liable to become reservoirs of water or gas, were dangerous neighbours, and from the point of view of safety alone, it would be desirable to fill them rather than to leave them open. He had recently heard of the existence at Gippsland in Victoria of vast brown coal-seams, one of which is over 500 feet thick. Some of these, it is stated, run under the sea. It would be interesting to watch the struggle between man and Nature when an attempt is made to invade that submarine reserve.

Prof. Arnold Lupton (Leeds) asked whether the percentage of ash in the Bore-hole seam—about 6¼ per cent.—was a fair average for one of the best seams of the district. The small thickness of ground left between the bottom of the sea and the coal-seam—120 feet—proved that Australian mining-engineers had strong nerves. He asked whether barriers were left between one colliery and another, so that if the 120 feet failed in one mine it would not drown out the whole district. With only 120 feet left as a roof below the sea, he thought that sooner or later, at some point or another, the sea would make an incursion into the workings.

Mr. T. E. Forster (Newcastle-upon-Tyne) said that the district described in the paper was one with which he was very well acquainted, his first experience of it being acquired by making, in conjunction with his father, the late Mr. George Baker Forster, a report on the working of this sea-coal. It was rather a difficult problem, as would be gathered from the paper, for it was a thick seam lying at a very shallow depth and having alluvial deposits, with water-bearing strata, on the top. Southward, the seam dipped towards Sydney, but near Newcastle there was an anticline and the dip was reversed, so that a piece of ground, round Stockton (full of hollows and holes, and apparently without any regular dip) formed a small coal-field, extremely difficult to work.

In his experience, a clay cover could not be altogether depended upon, for it might suddenly thin out in an unexpected way. He came across a case the other day in Cumberland, where a large sea-wall was being made. The foundations were all bored, and clay was expected for a considerable depth, but it was afterwards found that each bore-hole had gone down on the top of a ridge of clay, and that there were large depressions between, owing to the denudation of the clay. On the coast of Northumberland, at Cambois, they had for a long distance from 40 to 80 feet of clay all along the coast, but beyond a trouble it disappeared; and if such a trouble occurred running parallel with the coast-line, they could not tell whether or not the clay had disappeared. It was always best in fixing a limit to leave the clay out of consideration altogether, and to determine the thickness as if there was no clay present.

The working of coal under the sea at Harrington was one of the few cases in this country where the conditions were very similar to those mentioned in the paper. There, the seam, 7 to 8 feet thick, rising seaward, had a roof overlain by strata not unusually strong or watertight, and no alluvial deposits, and the outcrop of the measures probably ran into the sea-bed. In that instance, the Main band, probably, was first worked, about one-third of the seam was taken, and large pillars were left—he thought about 80 feet long by 70 feet wide. The top coal was left in the first working, but was afterwards taken down in the bords or wide places and left in the narrow places. That method was followed until the places began to approach the bottom of the sea, and the minimum limit was fixed at 126 feet. At that point they found in some of the working-places that there was a considerable quantity of salt-water coming from the roof, and these working-places were stopped; no further difficulty, however, occurred, and the workings were continued up to that point without interruption. The Six-quarter seam had since been successfully worked over the same area, and the coal taken out to a depth of 270 feet (not 360 feet as stated by Mr. Atkinson). The method of working was ordinary longwall, the stalls were carefully packed, there was 60 feet of good hard sandstone above the seam, and very little water had been met with.

In Appendix IV. to the paper, which appeared to have been mostly compiled from a paper by Mr. Thomas Bell, reference was

made to the disaster which occurred at Workington in the year 1837. In that case, the workings holed, not directly into the sea, but into an old sand-wash, and the scene of the disaster was close to the mouth of the river Derwent, which runs into the sea at Workington. The sand-bed was possibly an old mouth of the river, and its existence and its course must have been known before the date of the accident, because several trial-shafts were sunk, as shewn by the plans, early in the last century (about 1809) and abandoned. They drove out seaward at the northern end of the coal-field, then southward, and started to work inland and to the rise. Apparently they did not (as stated in Appendix IV.) rob the pillars. He came across an old man, a few months ago, who was working as a boy in this pit at the time of the disaster, and who told him that it was not through robbing the pillars; but, that, for some time previous to the accident, in the working-places which they were driving, heavy salt-feeders were coming through the fissures in the roof, together with fine sand, and that it was his duty to fill this sand away into tubs. So it was only natural to suppose, when they approached so close to the sand-feeder, that a heavy fall probably liberated the feeder, and this no doubt drowned the colliery.

He thought that further explanation should be given as to the working of the seams under the Permian limestone in Durham. Depths were recorded in the seventh column of Appendix III. of the coal below the water-bearing strata; these figures were probably correct at the points where the shafts were sunk, but coal-seams rise under the limestone so that, at the places where the coal-pillars were removed and the water-feeders brought down the thickness might be much less.

The barriers around the workings at the mouth of the Hunter river had been comparatively thin, but the Government reserved a barrier of 300 feet along high-water mark. The rule in New South Wales differed from the practice in this country, where every lease and every area stood by itself, as the conditions of each lease were considered by the Crown and by the lessee; but they had always gone on the assumption in this country that a hard-and-fast rule could not be made for every mine.

Mr. W. Spencer (Leicester) said that he was much interested in Mr. T. E. Forster's statement that considerable indications were

given before the inundation at Workington many years ago, but as no bodies were recovered there had been no inquest. In a comparatively shallow pit in South America, many years ago, he had heard the waves rolling overhead: the pit was sunk through a close bind, and he never heard of the occurrence of any influx of water. He had been informed that in a case in the county of Durham, in which the sand-feeder broke through, there were only 40 feet between the coal and the bottom of the sand. The water was brought down by too much coal being taken out in a second working.

Mr. JOHN GERRARD (H.M. Inspector of Mines) hoped that Mr. Forster would some day give the members a paper describing his experience of working under the sea on the east coast, of a seam above one which had been worked out. He had pleasure in moving a vote of thanks to Mr. Atkinson for his valuable paper.

Mr. JAMES STIRLING (Victoria), in seconding the vote of thanks, said that he had visited all the mines described, and could testify to the good work being done by Mr. Atkinson. It was clear that the Government of New South Wales had taken precautions to safeguard the lives of the miners in deciding that no mining should be carried on within 120 feet of the bed of the sea. It was probably a safe limit, but when visiting one of the pits he was interested in hearing what the workmen thought of the risks of working under the sea; they said that they certainly ran risks, but they got accustomed to the noise of steamers and other vessels passing over them, and when the noises were unusual or long-continued they persuaded the manager to put a few more bore-holes ahead for additional safety.

The PRESIDENT (Mr. J. S. Dixon) said that the information as to coal-mining under the sea, which was embraced in Mr. Atkinson's paper, formed a collection of facts which would be of great value to the members. In Scotland, there were large areas of coal under the sea. In one district, there was a large area in which the stoops were left unworked, because the superficial strata were mostly sand and gravel, filled with water. These were bored to a depth of 150 feet with the view of ascertaining whether the clay over the strata was continuous, but the borings cast a considerable amount of doubt upon it, and no attempt had been

made to remove the pillars. As regards working under inland lakes, he knew of one instance where in working at a depth of 150 feet, water was encountered; but, the bottom of the lake being composed of mud, the cracks silted up and the water ceased. Considerable liberties could be taken when working a seam under water, if a strata of mud or clay intervened, which would silt up the cracks as they occurred.

Mr. A. A. ATKINSON, replying to Mr. Bell's remarks, wrote that the usual width of bords in New South Wales was 24 feet, but Crown leases for coal under the sea stipulated that bords shall not be driven more than 18 feet wide, and the managers of the collieries have adopted the maximum width, except in winning-out or advance-places. Where the roof is tender and requires extra support, this is usually supplied by means of a wooden chock or "pigsty" as they are locally called, made of rough timber, 6 or 8 feet long, and built up in the same way as the hardwood chocks used in coal-mines in Great Britain.

Although the writer had particulars of the coal-mining operations in the Whitehaven collieries, as explained by Mr. R. W. Moore, he was not at liberty to disclose them in his paper read before the Institution.

In answer to the interesting remarks of Mr. H. M. Cadell, there were no workings, at present, more than ½ mile beyond high-water mark; and, so far, the thickest strata between the coal-seam and the bed of the ocean did not amount to more than 300 feet. Fire-damp, so far as the writer was aware, had never been seen in any of the workings under the ocean, and all the collieries working this coal as yet were using naked lights, the usual form being the Scotch miner's oil or tallow lamp. The remarks describing the extraction of pillars in the Mammoth seam at Shenandoah, U.S.A., were interesting, but having regard to the conditions as to character and thickness of strata and thickness of seam in the Newcastle ocean coal, he (Mr. Atkinson) was strongly of opinion that it would be inadvisable to make similar attempts to remove the pillars under the ocean, in the collieries described in his paper.

In reply to Prof. Lupton, it might be stated that the percentage of ash given, namely, 6¼, was a fair average of the best seam in the district. As to the thickness of strata agreed to be left in one case between the bottom of the sea and the coal-seam, it might

be pointed out that some managers had expressed opinions to the effect that in working under the ocean operations might be carried on safely with considerably less strata than 120 feet between the top of the seam and the bottom of the ocean. In regard to this matter, however, much depended on the character of the strata, a great safeguard (in any case) being a thick deposit of strong plastic clay.

The remarks of Mr. T. E. Forster were particularly valuable, inasmuch as he had an intimate knowledge of the locality dealt with in the paper, and also because of his connection with collieries working coal under the sea on the eastern and western coasts of the North of England. The disappearance of the beds of clay described by Mr. Forster showed the necessity, as he mentioned, of leaving out of calculation any deposits of clay found under the land, when fixing the safe limits of working coal under the sea. He (Mr. Atkinson) was pleased to read the corrections made by Mr. Forster, in regard to the depth at which the Six-quarter seam had been worked at Harrington, as well as the interesting history of the unfortunate disaster at Workington in 1837.

The vote of thanks was cordially approved.

# THE COAL-FIELD OF NORTHERN BELGIUM.*

By ÉMILE HARZÉ, Honorary Director-general of Mines.†

The recent discovery of coal beneath the moorlands of the Campine Limbourgeoise will have incalculable effects on the destiny of Belgium. But, as might have been expected, many false notions have arisen in regard to this hidden wealth. It was on this account that the present writer was induced to set forth, in a lecture delivered on May 7th last to the Société Belge des Ingénieurs et des Industriels, in the presence of H.R.H. Prince Albert of Belgium, all the known facts, dealing at the same time with the wellknown ancient Coal-measure valley, which from north-east to south-west traverses the Walloon districts of the country. The facts and considerations embodied in that lecture are supplemented by others in the present paper.

It was in Germany that the first impulse was given to the search for coal, which, being pursued from east to west, has resulted finally in the discovery of a new field in Belgium. There has never been a moment's doubt as to the synchronism of the ancient Belgian coal-basin and that of Westphalia. Fig. 1 (Plate XXXIII.) illustrates this correlation. Whereas, however, the breadth of the Westphalian coal-field (although not entirely determined, on account of the enormous thickness, on the north, of the overlying post-Coal-measure formations), exceeds 18 miles in the area already explored; at the Couchant de Mons, where the Belgian series is best represented, the distance between the southern and northern boundaries is only about 8 miles.

But it must be noted that, in Belgium, the strata are strongly plicated by thrust-folds in the southern portion of the basin, and that the uplift beyond the so-called southerly fault (which has a downthrow southward) has sliced off a portion of the Coal-measures. It may be added, further, that the coal-formation spreads out considerably to the east of Liége as the result of the central uplift, but is not so developed in depth as it is at the

* *Annales des Travaux Publics de Belgique*, 1902, vol. vii., pages 735 to 766.

† Translated and partly abridged by L. L. Belinfante, M.Sc.

Couchant de Mons. If some 80 miles north-east of the frontier-city of Aix-la-Chapelle, we take a transverse section through the Rhenish-Westphalian basin, passing by Bochum, we arrive at the result shown in Fig. 2 (Plate XXXIII.). The series is seen to consist (in breadth) of several depressions which determine valleys, as a rule continuously deeper down the farther one recedes from the southern boundary. These valleys correspond to the different zones of the basin, as they are generally termed. There is the zone of Witten, the southernmost of all; then successively comes those of Bochum, Essen, Emscher and Lippe, and it seems probable that yet others more to the northward, will sooner or later become available.

It is hardly necessary to repeat that, as in Belgium, the Rhenish-Westphalian basin is margined by Carboniferous Limestone, and, where this is wanting, by Devonian grit. Following westward the southern rim of this margin, both at the surface and below the newer strata which cover the Coal-measures, one circles round the great Devonian massif of Düsseldorf-Gladbach, finally turning south-westward towards Belgium (Fig. 1, Plate XXXIII.).

On the German side of the frontier the Devonian belt fringes the Wurm coal-field, and then enters Belgium west of Aix-la-Chapelle, passing a little distance south of the State coal-field of Limburg, a coal-field of comparatively small importance which the Belgian Government worked themselves before the Treaty of the Eighteen Articles, and which was farmed by the Netherlands Government in 1845 to the Maestricht & Aix-la-Chapelle Railway Company for a term of 99 years.

But as it extends into Belgium, the Wurm basin becomes barren immediately within the Belgian frontier, being represented only by mere patches of the basement series, and we then pass into the ancient rich metalliferous belt, comprising the famous deposits of Moresnet and Bleyberg. Farther westward only, in the direction of Liége, does the Coal-measure basin reappear, broader, deeper, and richer in seams.

As to the Carboniferous fringe, it enters Belgium by way of Bleyberg, runs to the south of the Herve district more or less parallel to the Vesdre river, passes by Angleur, south of Liége, then follows the right bank of the river Meuse as far as Engihoul, when it makes a double loop, crossing over to the left bank of the river and continuing to follow that up.

Aix-la-Chapelle is situated on the fringe itself, south of which opens up a secondary basin, neither very broad nor very deep. This basin, in which coal-seams have long been worked, is known as the Eschweiler basin. Little developed as it is in Germany, it dies out towards Belgian territory as the old submergence approaches the outcrop. The little coal-basins of the Condroz may, perhaps, be correlated with it. It would appear, however, from a note by Mr. G. Soreil, that the late Mr. J. B. Cornet was rather disposed to regard the Herve basin, separated by a fault from the Liége basin properly so called, as an outlying portion of the Eschweiler basin.

It is, at all events, interesting to examine the general aspect of the German Coal-measures just at the point where they extend into Belgium. Of this Fig. 3 (Plate XXXIII.) gives an idea. It represents a cross-section passing a little east of Aix-la-Chapelle, and shows the highly disturbed southern facies of the Wurm basin, then cuts into Dutch Limburg by Kerkraede, and extends towards Sittard, all the time in Coal-measures, the data having been gathered from the investigations made in that province during the past 30 years.

It will be observed that, at Kerkraede, the Coal-measures form an anticlinal arch, becoming immediately thereafter the southern flank of a Coal-measure valley. As will be seen later, this is the same valley that has been recently met with in Belgian Limburg. The same section cuts through, on the south, the Eschweiler basin. We may well say that Kerkraede is the key which opens up the coal-field of Dutch Limburg, and consequently also that of the Belgian Campine.

The writer is convinced that, but for the Treaty of the Eighteen Articles which split in two the ancient province of Limburg as it had been constituted after the events of 1830, the Government Mining Survey of Belgium would have thrown such light on the structure of the Kerkraede district as to hasten the systematic search for coal. It has indeed proved sufficient for a former engineer of that survey, a man of skill and originality, to be summoned on a journey of inspection and consultation in the surrendered portion of the province, to establish the favourable outlook for mining industry both there and in the Belgian area.

Before, however, considering how much is now known regarding the new Coal-measure valley of Northern Belgium, it will

be well to resume our sketch of the course of the old one, from Liége onwards.

A little distance south-west of the city of that name, geologically the central point of the Liége coal-field, where the basin is about 5,000 feet in depth, the bottom rises by very slow degrees towards Namur, cropping out at the streamlet of Samson, beyond Andenne (Fig. 4, Plate XXXIII.). As a result of this declivity, the breadth of the Coal-measure valley diminishes, while *pari passu* the seams successively disappear.

Farther yet, beyond Samson, the valley-bottom becomes again more marked, dipping generally towards Namur, Charleroi and Mons, while exhibiting local undulations. At Mons, the basin seems to be no less than 10,000 feet deep. Thanks to this great depth, the valley contains a large number of coal-seams, the products thereof varying in character from gas-coal to anthracite.

Farther westward still, the Coal-measure valley enters France by Valenciennes, describes a great curve across the departments of the Nord and the Pas-de-Calais, and then extends into England south of London, to join up finally, in all probability, with the South Wales coal-field.*

This huge Carboniferous valley is, in Belgium, more or less parallel to the great formation of grits, shales and limestones of the Condroz. At certain points in the latter are local depressions, showing traces of former small coal-basins which have been all but entirely swept away by aqueous agencies.

Among these fragmentary remnants is the little basin of Clavier and Bende, 9 miles south of Huy, not far from Modave, cut in two by a longitudinal ridge of Carboniferous Limestone. This basin, wherein two coal-seams of poor quality were at one time worked, comprises a little bit of the province of Luxemburg; and it is a fact not generally known that, in consequence thereof, Luxemburg province figured in the Belgian statistics of coal-output, from 1841 to 1850, for a mean annual production of 600 tons.

We may enter now upon the history of the search for coal in Northern Belgium. The idea that a northern coal-field does exist there is no new one. A trial-boring was put down, more

* See Mr. Ad. Firket's paper on the extension into England of the Franco-Belgian coal-field, *Revue Universelle des Mines, etc.*, second series, 1882, vol. xii., page 457; and *Annales de la Société Géologique de Belgique*, 1883, vol. x., page xciii.

than 40 years ago, by a French company, near the little town of Menin. This boring, although in Belgian territory, formed part of a series of trials made to the north of Lille, with the view of striking a second Coal-measure valley. The boring, after passing through Tertiary and Secondary deposits, reached at a depth of 577½ feet from the surface, bluish-black shales, through which it was carried down for another 393 feet. According to Prof. G. Dewalque, these schists belong to the Coblentzian group of the Devonian.*

It may be added that none of the borings that have been undertaken in Belgium for the purpose of opening up water-supplies, north of the old Carboniferous valley, have struck Coal-measures, although they have reached or passed into Palæozoic rocks. Among the localities where such borings have been put down may be mentioned Ostend, Ghent, Alost, Brussels, Louvain, Saint Trond, and (quite recently) Malines.

As to the origin of the search for coal in Dutch Limburg it must be sought, as we have seen, in the workings carried on in the Kerkraede district, and more to the north still, in the exploration-work, etc., undertaken close to the frontier in the Wurm basin. The search went on west of Kerkraede, at first rather nonchalantly, then with feverish activity, induced by the wonderful prosperity of the coal-trade in 1873. The investigation was carried on by Germans or Dutchmen, with whom some Belgians had entered into partnership.†

* *Bulletin de l'Académie Royale de Belgique*, series 2, 1862, vol. xiii., page 201.

† The report of the operations conducted by the Société de l'Union minérale pour la Néerlande (Netherlands Mineral Union) from 1856 to 1857, translated by Mr. Eug. Bidaut in vol. xvi. of the *Annales des Travaux publics de Belgique*, page 241, gives a summary of the ideas which were then current as to the probable mineral wealth of Dutch Limburg. For instance, Mr. Van Swieten, general manager of the above-mentioned corporation, wrote as follows: "When we consider how near is the frontier of the Netherlands to the Ruhr coal-basin, a basin which was formerly supposed to lie far behind the right bank of the Rhine, although nowadays its boundaries have been advanced far on the hither side of the left bank; when we note that the coal-basins of Aix-la-Chapelle and Liége stretch out towards Limburg, in such wise that two coal-mines are worked at Kerkraede on Dutch soil; when we see smoking within gunshot of our frontier the chimney-shafts of the lead- and zinc-mines of Bleyberg and La Vieille-Montagne; when, finally, we ascertain that there is no essential difference between the geological structure of Dutch territory and the contiguous portions of foreign dominions, we find in all these considerations powerful inducements to devote ourselves to the enterprise that we have in hand, especially in such times as these in which we live, when investigation and experiment are applied to everything that cannot be demonstrated as absolutely impossible." And farther on, he says, "The extension of the Coal-measures beyond the concession of Kerkraede in the Duchy of Limburg is now fairly probable, as our researches have made it clear that the Coal-measure formation of the Wurm district is identical with that of Belgium, and that the point

The borings and a few shafts showed that the coal-basin was prolonged from east to west, besides extending northward, and that consequently it approached the territory of Belgian Limburg. The character of the coal in the various seams that were struck proved the basin to be much richer than had previously been supposed.

In 1876, Mr. Guillaume Lambert, professor of mining at the University of Louvain, formerly engineer of the Liége School, and of the Belgian Mining Bureau, was called upon by a private company to give them his opinion as to the researches undertaken in Dutch Limburg. After emphasizing the importance of these researches the eminent engineer, in view of the correlation established with the great coal-basins of Germany, expressed the opinion that both Dutch Limburg and Northern Belgium are areas which might well contain the prolongation of the coal-field. Mr. Lambert's report embodies interesting observations, not only on the synchronism of the Limburg deposits with those of the Westphalian basin, but also on the correlation thereof with the coal-fields of England.* His pupil and present successor at the University of Louvain, immediately embraced the views of his teacher. The writer is alluding to Mr. André Dumont, son of the celebrated Liége geologist, whose scientific discoveries created so great a sensation in the learned world.

While merely considering the probability of the extension of the new basin into the northern part of Belgium, Mr. Dumont, in a memoir published in 1877, proposed that the Belgian Government should encourage, or even itself initiate, boring operations in the northern provinces. Besides settling the question whether

where these two coal-fields join up is precisely somewhere within the Duchy of Limburg. This is a fact, to the establishment of which special attention will subsequently be devoted."

The report lays stress on the proximity of the metalliferous mines of Bleyberg and La Vieille-Montagne, as well as on that of the collieries of Wandre, Trembleur, etc. Finallly, it records the discovery of Coal-measures near Mesch, a locality within Dutch territory, some 2½ miles north-east of Visé, as also the existence of traces of old prospecting or exploration-work there. In his report of 1876, which will presently be dealt with, the engineer, Mr. Guillaume Lambert, states that twenty years previously the Netherlands Mineral Union had undertaken the search for coal, but had not pushed investigations far enough to the north. From this same report, however, it is evident that coal was at all events thought to exist in the neighbourhood of Sittard, since a mining concession appears to have been granted thereabouts under the French régime. Doubtless in 1856, as in former years, people preferred to confine their exploration-work to an area easily accessible by means of pits. Hence this preference for confining investigations to the southern part of the field.

* *Trans. N.E. Inst.*, 1876, vol. xxvi., page 15.

such a probability was to become a certainty, the proposed borings would furnish valuable information as to the geology of the country. It does not appear that the Government was formally petitioned to undertake the work, and the proposal was simply the expression of a hope, such as that which we would now express in regard to the Dutch Government—namely, that it should undertake fresh researches in the southern portion of the Netherlands.

Meanwhile, so far as Belgium is concerned, the investigations that were being privately pursued lent daily increasing interest to the problem, and three years ago it found its place on the agenda-paper of the Société géologique de Belgique, domiciled at Liége. As a result, several interesting papers were brought forward, among which must be cited those of Messrs. A. Habets, M. Lohest, H. Forir, G. Velge, X. Stainier, J. Van Ertborn, G. Soreil, G. Dewalque and S. Vrancken. Many of these papers were accompanied by diagrams, and they all laid stress, not only on the probable extension of the coal-field of Dutch Limburg into Belgian Limburg, but also on its great depth and its probable prolongation into the province of Antwerp.

The present paper has been largely built up from those just mentioned, more especially the communications of Messrs. Lohest, Habets and Forir, and the present writer has made extensive use of Mr. Forir's diagrams.

We cannot pass over in silence the studies conducted by the late Mr. Rénier Malherbe, on the northward extension of the Coal-measures of the province of Liége. While the investigators to whom reference has been made, started more or less directly from the neighbourhood of Kerkraede to discover coal in the very heart of Dutch Limburg, Mr. Malherbe took as his starting-point the then northernmost colliery of the Liége basin, in order to trace the extension of the coal-field towards, if not into, Limburg itself. He followed up his studies by important exploration-work which has assured to his heirs the grant of what is now the most northerly concession in the Liége basin, on the left bank of the Meuse.

In conducting an official enquiry into the facts adduced by Mr. Malherbe, the present writer had occasion to find out that, about half a century ago, the search for coal was undertaken by a company to the north-west of Visé. Little shafts were put down

on both sides of the frontier, at Mouland in Belgium and Mesch in Holland. Perhaps these investigations may be associated or connected with those mentioned in a footnote as having been conducted by the Netherlands Mineral Union. Coal was actually got in Holland, but it must have been of very poor quality, for all this exploration-work came to nothing.

The enquiry led the present writer to project a boring near the canal from Liége to Maestricht, more or less opposite Eysden,* the first village of Dutch Limburg on the right bank of the Meuse. Following up no doubt the same order of ideas, Prof. Lohest, quite independently, suggested that a boring be put down at Eben-Emael. The two localities, by a sort of coincidence, happened to be close together, and, so to say, on the same parallel. The notion was to have a series of borings from south to north, taking duly into account such deviations as might be suggested by the first results obtained. We should then have seen what becomes of the anticline of Kerkraede.

We now come to the researches undertaken in Belgian Limburg as a direct consequence of those carried out in Germany and in Dutch Limburg. The first company to organize a search in Belgian territory for the extension of the Dutch coal-basin was formed by Mr. Jules Urban. Researches were begun in 1897 at Lanaeken, a short distance north of Maestricht. On account of an accident to the apparatus, the first boring had to be abandoned, so another was put down close by. This one, after going through sundry sands, clays and marls, is said to have reached, at a depth of 886 feet below the surface, a shale of supposedly Coal-measure age. It soon got into the blue limestone of Visé, and was then stopped on account of another accident. The result would in any case have been unsatisfactory, once the limestone had been proved. Nevertheless, as Prof. Lohest remarks, the Lanaeken boring threw much light on the problem that was being studied: the mere occurrence of Coal-measure strata in that locality was of fundamental importance. It cannot be denied, however, looking back on the experience of past years, that Lanaeken was a good locality to select for a first boring. It was on the left bank of the Meuse, facing, so to say, the Dutch formation as it was supposed to exist.

* This locality is not to be confounded with another of the same name, 9½ miles north of Maestricht.

Then too, as the putting down of a shaft had to be kept in mind, it was desirable to avoid too great a thickness of overlying barren strata.

Mr. Urban did not make a fresh attempt elsewhere. Doubtless he was looking for the results which would follow from the renewed search undertaken by others far to the north, when death deprived his country of a man remarkable for his energy and initiative. In recording the history of the discovery of the prolongation of the Dutch coal-basin into Belgium, it would be unjust to slur over the credit due to the eminent engineer whose name has just been mentioned, the more so that all subsequent investigators made use of the landmark which he had determined.*

It was at the end of 1898 or the beginning of 1899 that Prof. Dumont began to test his hypotheses by means of exploration-work. After having founded a syndicate for the purpose, he put down his first boring at Eelen, 12½ miles north of Lanaeken, and a few miles south of Maeseyck. In selecting a locality so far north, Prof. Dumont was doubtless guided by the results obtained in the Dalheim boring, in Prussian territory, near Roeremonde. This boring had been carried out by Mr. Raky, the skilled expert with whom Prof. Dumont contracted. The Eelen boring was carried down to the enormous, and evidently unexpected, depth of about 2,950 feet, and was then stopped on account of an accident to the apparatus. A good deal of mystery was made about the nature of the strata that had been bored through, and we know merely that the Coal-measures were not struck, but that the boring was stopped in red grits, which were first reached at a depth of 1,970 feet. To what formation do these grits belong? Are they of Devonian age? If so, the result of the boring is purely negative, but it should reveal a most instructive series of cores. Are the grits more probably, as many observers believe, Triassic red grits (Vosges Sandstones)? Then the result is indecisive.

But nowadays doubt is no longer possible; apart from the evidence gathered in Germany, the borings farther west, those of

* Mr. Urban's chief co-workers were the late Mr. Val. Putsage, engineer of the Mons School, and Mr. Em. Flasse, borer at Athus; the last-named had played a part in the investigations conducted in Dutch Limburg. In regard to every first boring, we may note that the mining explorer takes a leaf out of the book of the gunner. Just as the latter corrects his aim according to the spot where the first shell bursts, so the former maps out and modifies his area of search according to the results yielded by the first boring. The history of mining discovery affords numerous examples of this procedure.

Opoeteren and Guitrode, have confirmed the existence of similar strata in the Campine district.* In reaching the red grit at a depth of 2,625 feet, the Guitrode boring proves that the top of that formation slopes down to the west, in consequence probably of the erosion of its uppermost beds. At all events, the great depth at which the Coal-measures must lie, both at Eelen and at Guitrode, as also at Opoeteren, precludes the successful initiation of mining enterprise there.

But Prof. Dumont did not lose heart; with admirable perseverance, and a robust faith in final success, he formed a fresh syndicate and put down a new boring in the neighbourhood of Asch, about 6¼ miles west of the line joining Lanaeken to Eelen. There he was much more fortunate, and struck the Coal-measures apparently at a depth of 1,740 feet from the surface. From that level downward the boring is said to have traversed an alternation of shales and grits with some coal-seams. An important point is that the coal is said to be very rich in volatile matter. As to the formations which overlie the Coal-measures the same mysterious reticence was observed here as at Eelen; and, knowing how discreet it behoves the Mining Bureau to be in the matter of such investigations, the present writer has refrained from questioning the officials. Hence, there is some slight uncertainty in regard to some of the information embodied in this paper.

However that may be, if to the late Mr. Urban be due the credit of having made the first plunge, and having been the first to strike the Coal-measures in Belgian Limburg, to Prof. Dumont belongs the great honour and the great satisfaction of having obtained the first specimens in that district of a coal, which, when worked, will prove an important factor in the future destinies of Belgium.

With the view of obtaining one or more mining concessions Prof. Dumont pursued actively his investigations, while his preliminary success attracted other explorers to the district. The field open to search is vast enough for all.

The John Cockerill Company had already in 1898 participated in the boring operations carried out in Dutch Limburg. In consequence of the altered attitude of the Netherlands Government in

* The relative distances of these borings from that of Eelen are as follows:—Opoeteren, 3 miles west, and ¼ mile south; and Guitrode, 4 miles west, and about ¾ mile north.

the matter of concessions, and of the publication of the discovery of coal in the neighbourhood of Asch, the company unhesitatingly joined in the search for coal in Belgian Limburg. The conduct of operations was confided to Mr. Verbunt, who had already given to the company the advantages of his services on the right bank of the Meuse. Simultaneously two important colliery companies of the Liége basin,* entrusted the Tiefbohr-Aktien-Gesellschaft vormals Hugo Lubisch, of Düsseldorf, with the putting down of borings in the Limburg portion of the Campine district.

These researches having been crowned with success, the aforesaid companies placed the information that they had obtained and their boring experts at the disposal of third parties, the engineers Messrs. Paul and Marcel Habets taking over the general direction of the investigations carried out by the Masy-Wittouck-General-Thorn syndicate and by other associations. Other companies entrusted the Dumont syndicate with the conduct of their boring operations, that syndicate having secured the monopoly in Belgium of the Raky process. We know that still other companies have been formed and are in process of formation. By June 10th, 1902, thirty borings had been put down, from the Meuse up to Westerloo and Santhoven in the province of Antwerp. Thickly dotted about between the meridians of Asch and Béverloo, these borings leave great unexplored gaps between them from Beeringen to Westerloo, and from that locality to Santhoven. Others are in preparation or projected in the province of Antwerp.

The essential results of most of these borings are now known. The three most northerly of them in the province of Limburg, namely Eelen, Opoeteren and Guitrode, have been stopped at great depths (from 2,300 to 2,950 feet) in the Trias. Nine, to our positive knowledge, have traversed coal-seams, after striking the Coal-measures at depths varying between 1,300 and 2,000 feet (in round numbers). The boring which has gone deepest down in the Coal-measures is that of the Masy-Wittouck-General-Thorn syndicate. Striking that formation at a depth of 1,970 feet, it traversed thirteen seams of coal in a thickness of 985 feet of strata. The actually explored length of the belt, in the part recognized as containing coal-seams, is 18½ miles.

* *The Société de l'Espérance-Bonne Fortune*, and the *Société de Patience-Beaujonc.*

Fig. 4 (Plate XXXIII.) reproduces, almost in its entirety, Mr. Forir's new map which shows by contour-lines the relief of the concealed Palæozoic surface in Belgium. An attentive study of the results yielded by nineteen artesian borings in Brussels and its suburbs confirms on the whole the track of the 164 feet (50 metres) contour as plotted out by Mr. Forir, but whether it turns westward in quite the way shown by him appears problematical.*

Mr. Forir attributes the hidden ridge of Brussels-Malines to erosive agencies, although he does not exclude the hypothesis of a tectonic origin. The present writer will refrain from expressing a decided opinion, although he is inclined to regard the ridge as a Palæozoic uplift. This question will be probably resolved by the operations now being carried out at Santhoven.

The character of the coal that will be eventually struck west of Beeringen, as well as at Westerloo and at Santhoven will possibly furnish some indication as to the rise in level of the bottom of the basin. The borings in these localities will be of all the greater interest that they may well reveal changes in the general facies of the Coal-measures.

Fig. 1 (Plate XXXIII.) shows the approximate underground contours which fall within its area, as well as the hypothetical track of the seams recognized in Dutch Limburg, in accordance with the correlation plotted out by Mr. Sassemberg, mining-engineer at Bochum, and also reproduced by Mr. Forir. According to these data, the Netherlands basin, the two slopes of which come out clearly, would seem as if it should die away towards the Meuse, perchance reappearing in Belgium in consequence of a change in the lie of the strata. This might come about, say, by an inversion of the synclinal axis of the Coal-measure valley, a doubling back northward on the west, or by a deep drop of the whole of the Palæozoic on the downthrow side of a north-and-south fault in the neighbourhood of the Meuse.

We may note, on the other hand, that there are considerable differences between Mr. Sassemberg's hypothetical chart and the mining map of Mr. Blanckvoort, on which latter Prof. Alf. Habets commented in a special paper.

Whatever may be the hypotheses enunciated, one fact remains certain, namely, that an important coal-deposit lies near

* Perhaps this marks the existence of a fault, which alters the level of the Palaeozoic formations in the neighbourhood of Antwerp.

Asch, that it has been struck again at Genck, 5 miles south-west of the former locality, and more recently still at points continually farther west, as far as Beeringen, south of Béverloo.

The coal obtained in the first two borings contains, it would appear, 45 per cent. of volatile constituents, and is comparable with the Flénu coal of the Couchant de Mons. This comparison implies that the deposit is both very deep and very broad; and the relative breadth would seem to be the greater here, that at the Couchant de Mons the strata are considerably plicated on the south and that the so-called southerly fault has razed off a portion of the deposit. In the new basin the seams seem to lie always flat.

We may observe that in certain borings striking not very dissimilar horizons the coal obtained had only 18 per cent. of volatile constituents, a fact which leads one to infer the existence of faults. If such faults turned out to be numerous they would constitute an unfavourable factor in the future working of the coal-field.

It would be important to know where lies the southern boundary of the new basin. In Dutch Limburg, the basin seems to be connected with that of the Herve plateaux by the Kerkraede anticline. But, proceeding westward, the Coal-measure anticline, eaten into at certain points by denudation which has laid bare the summit of the limestones, probably disappears ere long by the separation of the two valleys. This much is proved by the discovery of Silurian rocks in a boring put down for water, north of Saint Trond. Fig. 5 (Plate XXXIII.) shows the postulated separation: the early Palæozoic massif which divides the two basins can only increase the farther west one goes. The determination of the southern boundary of the new basin would be all the more useful that it is in approaching that line that one may hope to strike the Coal-measures nearer the surface, with every prospect, at the same time, of finding seams sufficiently rich to repay working.

If the present writer's old project, practically synonymous with that of Mr. Lohest, were carried out—that is, if a series of borings were put down from south to north, starting at the most northerly known point of the Liége coal-field, data of considerable value in this regard would be obtained. As matters stand, however, it would be better, in order to reach more immediately practical results, to put the borings down from north to south,

taking as a starting-point one of the best-known localities of the Limburg basin.

One circumstance connected with the Palæozoic contour-lines will strike the observer—namely, that they run much closer together at the meridian of Asch than at that of Antwerp. This implies that the Palæozoic drops much more rapidly below the barren strata in the former locality than in the latter. It will be noted, moreover, that despite sundry deviations, the general trend of the contours is from south-east to north-west.

A further point is that many townships of the Campine district, as also the camp of Béverloo, form part of, or lie opposite to, in the Palæozoic of an embayment whereof the western shoulder is clearly marked out towards the Brussels-Malines ridge, and beyond it the declivity of the Palæozoic continues to diminish.

From what precedes it will be inferred that if a boring were put down north of Antwerp, somewhere about Brasschaet, the Palæozoic would probably be struck at a less depth than at the village of Asch, the more probably that the general surface of the Campine district slopes downward to the Scheldt. Will the Palæozoic north of Antwerp turn out to be Coal-measures? An answer can only be given after some further investigations have been carried out. Suffice to say here that the Asch deposit appears to trend that way, and the great Yorkshire coal-field may well mark the north-western extremity of the Coal-measure valley. Along the whole line in Belgium are vast domains belonging to the State: the camp of Béverloo, the artillery-range of Brasschaet, the lands attached to the asylums of Hoogstraeten and Merxplas, the bed of the Scheldt itself and the lands appertaining thereto.

The Mining Act of May 2nd, 1837, was a reactionary enactment in favour of the surface-owners, giving them a preferential right in cases of competition, especially if they are the discoverers of the hidden minerals. The present writer has consequently expressed the opinion that the State itself should undertake a methodical search for coal in its vast domains of the Campine district.* On the other hand, Senator Hanrez has proposed a much more radical measure. He suggests the reservation as State property of two zones in the new coal-field. The first would be comprised within two vertical planes 15½ miles apart, trending

* *Annales de la Société Géologique de Belgique*, 1902, vol. xxix., page M 112.

south-west and north-east, the easternmost passing through Hasselt. This area would include a good deal more than the camp of Béverloo. The second would comprise all the subsoil to the west of a vertical plane, of the same trend as the others, and passing 9½ miles east of Antwerp. The Senator does not propose that the State should itself work the Domanial mines, as the enterprise would prove far too costly.

It does not lie within the scope of the present paper to discuss either of the foregoing proposals. We may note, however, that although in possession of State mines in the Saarbrücken and Upper Silesian coal-fields, the Prussian Parliament has just voted a sum of £2,880,000 for the purchase of several important Westphalian collieries, in order that the Navy and the State railways may be more independent of the vagaries of the coal-market. Then, too, the Netherlands Government, which has within recent years granted a certain number of mining concessions, has now resolved to grant no more, wishing for similar reasons to reserve a mining domain to the State. The Prussian Government hopes to weigh on the coal-market in favour of the metallurgical industry of the country.

We may now consider the character of the overlying barren strata. Although the veil of mystery which surrounded the borings has been to some extent lifted, the information which we possess in regard to these strata is still incomplete. All we know is that they comprise Quaternary, Tertiary and Secondary formations, and therefore must consist of peat, gravels, marls, various sands and clays, flinty beds, chalk, grits, etc. An important point is that the Triassic, hardly recognized as present at all in Belgium hitherto, appears to be undoubtedly proved in the borings of Eelen, Opoeteren and Guitrode. It is quite possible that the Permian may be found below it, and above it, in all the northern region of the country, the Jurassic. This foreshadows the future discovery perchance of ferruginous ores and salt-deposits. The strata that certain investigators fear to meet with are the redoubtable Aachen Sands at the base of the Cretaceous; these are great holders of water, and actually quicksands.

The difficulties that lie before the shaft-sinker are sufficiently apparent, and yet at the present day the putting down of borings seems to have degenerated into a sort of scamper—to such a degree

that one is inclined to ask whether the people concerned are aware of the importance of obtaining and preserving carefully samples of the rocks passed through. It is true that the most modern systems of boring are not favourable to proper sampling of the rocks.

The extreme rapidity of the boring operations, conducted mostly by Germans, in the Campine district, may be in part explained by the legal and administrative conditions which attach to the grant of mining concessions in Germany. The conditions are, however, far otherwise in Belgium.

If we take the case of an investigator conducting actively and methodically a boring at a locality selected after careful study, it does not appear to accord with strict equity that a competitor should be allowed to cut the grass from under his feet, by putting down in the immediate vicinity a boring by some extra-rapid process of which he may chance to possess the monopoly. Moreover, the very rapidity of the work would in all likelihood preclude an adequate investigation of the overlying barren strata. If this sort of monopolization of mineral wealth, contrary to the public interest which it is the province of the law to uphold, were allowable, many persons would agree that the system of granting concessions should be replaced by some other.

It remains to consider the period within which we may look for the opening up and working of the new coal-field. Great difficulties will have to be overcome in sinking shafts through the enormous thickness of barren, water-bearing strata in the Campine district, particularly where sands occur deep below the surface. It is true that the freezing-process, recently successful once again, at Harchies in Hainaut, will prove of great assistance, especially with the improvements lately introduced by Mr. A. Gobert. Evidently, then, a considerable expenditure of capital and time will be necessary ere the new collieries can set to work. A brilliant future lies before the Campine, considering that here is a rich coal-field, at a great depth it is true, within easy reach of the sea. Belgium may hope to build up a great export trade in coal by sea, and thereby create a new merchant fleet which will bring as return-cargoes to the Campine the ores already needed by the nascent metallurgical industry there. This implies also a more complete fusion between the Walloon and Flemish elements

of the nation; in fact, the consequences will be in every way far-reaching and should be carefully thought out beforehand.

A consideration of the statistics of the Belgian output of coal from 1831 to 1900 shows that in the last decennial period (1891-1900) that country produced more than seven times as much coal as in the first decade (1831-1840). On the other hand, the ratio of increase in output is diminishing, and would continue to diminish were it not for the discovery of the new coal-field. This, in the present writer's opinion, will have the effect of augmenting again the ratio of increase.

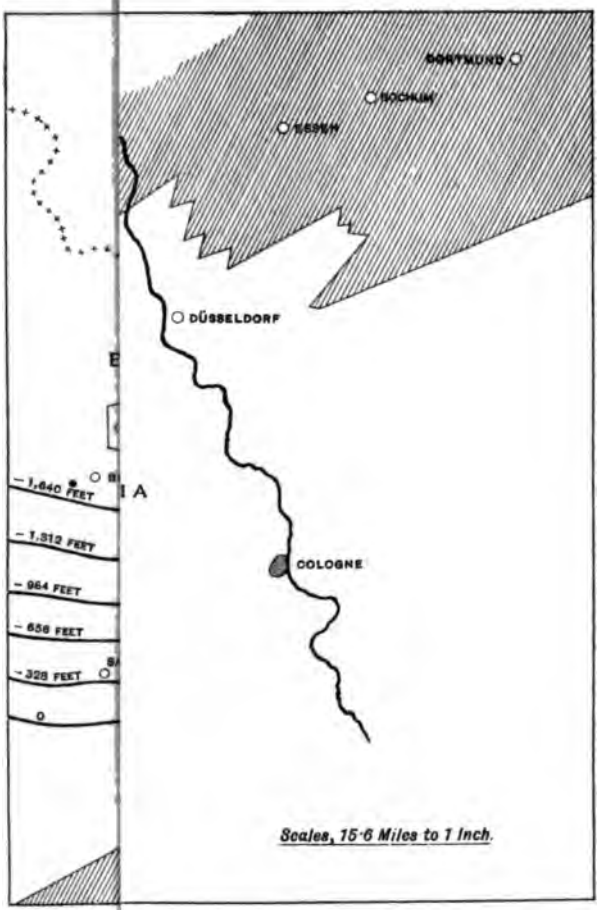
## Appendix.

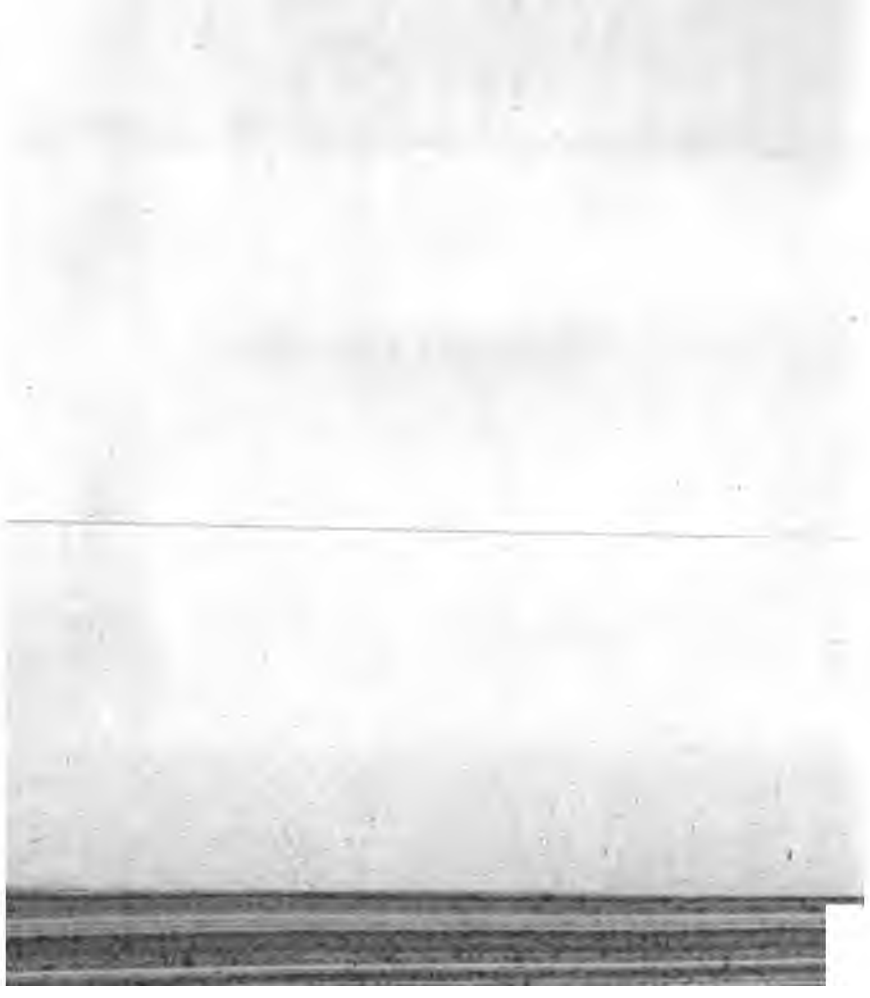
Since writing the above, the author has learnt that coal has been struck in two new borings. The first, conducted at Lanklaer by the Raky process for the newly-founded Charbonnages du Nord de la Belgique (North Belgian Colliery Company), was put down 4½ miles east of Asch, and does much to fill up the gap which existed in our knowledge of the strata between that locality and the Meuse.

The second boring was put down at Westerloo by the Vogt process on the estate of Count de Mérode, 12½ miles west of the boring which had struck the coal at Beeringen. It proves the passage of the Coal-measure formation into the province of Antwerp. The distance between the Westerloo and Beeringen borings is considerable, greater than that between the first borings put down in Belgian Limburg and those which had preceded them in Dutch Limburg; but there the fact that the Coal-measures passed from the eastern to the western region of the Meuse basin was previously surrounded with great uncertainity. The extreme distance between the borings which have struck coal in Limburg and those that have done so in the province of Antwerp is 34 miles, which is about the same as the distance from Quiévrain to Charleroi.

In his opening speech to the Provincial Council of Limburg, on July 1st, 1902, Baron H. de Pitteurs-Hiégaerts announced that 15 requests for mining concessions had been received and advertised, covering an area of about 75,000 acres. It is true that some of them overlap. Further requests for concessions are being received.

of Northern Belgium".





# BORING IN JAPAN.*

By F. J. NORMAN.

*Artesian Wells.*—Japanese farmers in Chiba-ken carry on nearly the whole of their rice-cultivation, amounting to tens of thousands of acres, by a free use of artesian wells, one well as a rule sufficing for three acres of wet paddy-land, and costing from 20 to 25 yen, or, say, from £2 to £2 10s. Such wells are sunk to depths of 300, 480 and 720 feet below sea-level, and the depths necessarily increase the farther one goes inland. For instance, there is a Buddhist temple some 5 miles inland, and the well is 960 feet deep. This well would probably cost from 300 to 500 yen, and would take from three to four months to sink. A well, 300 feet deep, on the other hand, seldom takes more than one or two weeks to put down. Fortunately for the farmers, the well-sinkers meet with nothing but sand and clay until the first water-bearing strata are reached.

These wells are bored by the *Kazusa* system, which is capable of dealing with hard rocks. Some years ago, a number of local well-sinkers were engaged by a Japanese syndicate to make a trial-boring for oil in the province of Echigo. The bore-hole was taken down to a depth of 1,200 feet; but, unfortunately, no oil-bearing strata were tapped. The work was very hard, quite half of it being through rock; but it was completed by two gangs of 6 men each in eight months, although the work was much delayed by the tapping of two distinct water-bearing strata. This well, is, the writer believes, the deepest yet sunk in Japan by the Kazusa system, but there appears to be no reason why deeper wells should not be sunk, as the capabilities of the system have not yet been thoroughly tested.

* The illustrations are reproduced, by permission, from *The Indian and Eastern Engineer*, 1902, vol. x., pages 119-124.

*Chinese System of Boring.*—According to Abbé Imbert, the Chinese in the province of Sze-chuan employ a very similar method when boring for oil, in the course of which they go down as deep as 1,500 to 1,800 feet, the wells being from 5 to 6 inches in diameter. He states that "the mode of proceeding is this:—If there be a depth of 3 or 4 feet of soil on the surface, they plant in this a tube of hollow wood surmounted by a stone, in which an orifice of the desired size of 4 or 5 inches has been cut. Upon this, they bring to work in the tube a rammer of 300 or 400 pounds weight, which is notched, and made a little concave above and convex below. A strong man, very lightly dressed, then mounts on a scaffolding, and dances all the morning on a kind of lever, that raises this rammer about 2 feet, and then lets it fall by its own weight. From time to time, a few pails of water are thrown into the hole, to soften the material of the rock, and reduce it to pulp. The rammer is suspended to a rattan-cord, not thicker than your finger, but as strong as our ropes of catgut. This cord is fixed to the lever, and a triangular piece of wood is attached to it, by which another man, sitting near, gives it a half-turn, so as to make the rammer fall in another direction." He thereupon describes how the reliefs are arranged, how the work is kept up day and night without intermission, and then says:—"When they have bored 3 inches, they draw up the tube, with all the matter it is loaded with, by means of a great cylinder, which serves to roll the cord on. In this manner, these little wells or tubes are made quite perpendicular, and as polished as glass. . . . . When the rock is good, the work advances at the rate of 2 feet in 24 hours, so that about three years are required to dig a well."*

This Chinese system of boring is so like the Japanese, that the writer cannot help thinking that the Kazusa system owes its origin to Sze-chuan; because the Japanese have in the past been as keen borrowers of Chinese ideas and notions as they now are of Western methods. The writer has not seen the Sze-chuan system, but it cannot possibly be simpler than the Kazusa system, and perhaps, and most likely, the latter is the best of the two.

*Kazusa System of Boring.*—Should a farmer or householder feel desirous of sinking a well, he will send for one of the local

* *The Chinese Empire*, by Abbé Huc, 1859, London, pages 188 and 189.

well-sinkers; and, after explaining to him for what purpose the water is required, get him to fix upon the spot, where it will be best to have it sunk, as also the price to be paid. The contract may be a verbal or written one, but it is invariably stipulated—no water, no cash.

It is just as well to say that the dowser or water-finder is not an unknown personage in Japan. As a rule, he is the boss well-sinker, the owner of the outfit necessary for the work to be taken in hand. To arrive at a correct idea of the monetary value of such an outfit, the writer suggested to a local well-sinker that he should suppose his house had been burned to the ground, and that all his well-sinking apparatus had been consumed in the flames; and he was then asked what sum of money he would require to replace it all. His answer was to the effect that, if he bought a complete and perfectly new outfit from another well-sinker, he would have to pay from 150 to 200 yen; but that this was never done, as Japanese well-sinkers take pride in being able to make everything required, except the carpentry tools, the steel crow-bar or rammer, and the two iron tubes used for removing the débris and the superfluous water. He then went on to say that, with a month to spare and with a capital of from 50 to 70 yen, he would easily be able to set himself up again in business.

The contract for sinking the well having been made, the boss of the well-sinkers will then collect his gang of workmen, generally consisting of five men besides himself, and a boy to run messages and hand things as required. In erecting the necessary scaffolding, they use 6 inches timbers and lashings of rice straw-rope. A smart gang will erect this scaffolding in about 1 hour's time, and when all is secure the reel or drum is mounted as shown in Fig. 1.

The sides of the reel are made of planks, 14 feet long, 6 inches broad and about 1¼ inches thick. Six to eight planks are required on each side, and in the centre of each is cut a circular hole about 1½ inches in diameter. Through this hole, and tightly fitting into it, passes an iron shaft, about 4½ feet long. To prevent the opposite sides of the reel or drum from closing in upon each other, that portion of the shaft, lying between them, is run through a hollow and somewhat loosely fitting bamboo,

about 2½ feet in length. The projecting ends of the iron shaft rest upon strong posts, firmly braced to and supported by the scaffolding. They rest in hollows cut to receive them, and an

FIG. 1. HEAD-GEAR OF BORING-PLANT.

U-shaped iron spike is driven in over them, so as to minimize the danger of the shaft jumping from its bed. The outer ends of the planks, forming the sides of the reel, are kept opposite to

each other by pieces of wood, about 3 feet long, 3 inches broad and 2 inches thick, fixed in crosswise as shown in Fig. 1. The side planks being spread out like the spokes of a wheel, two bands

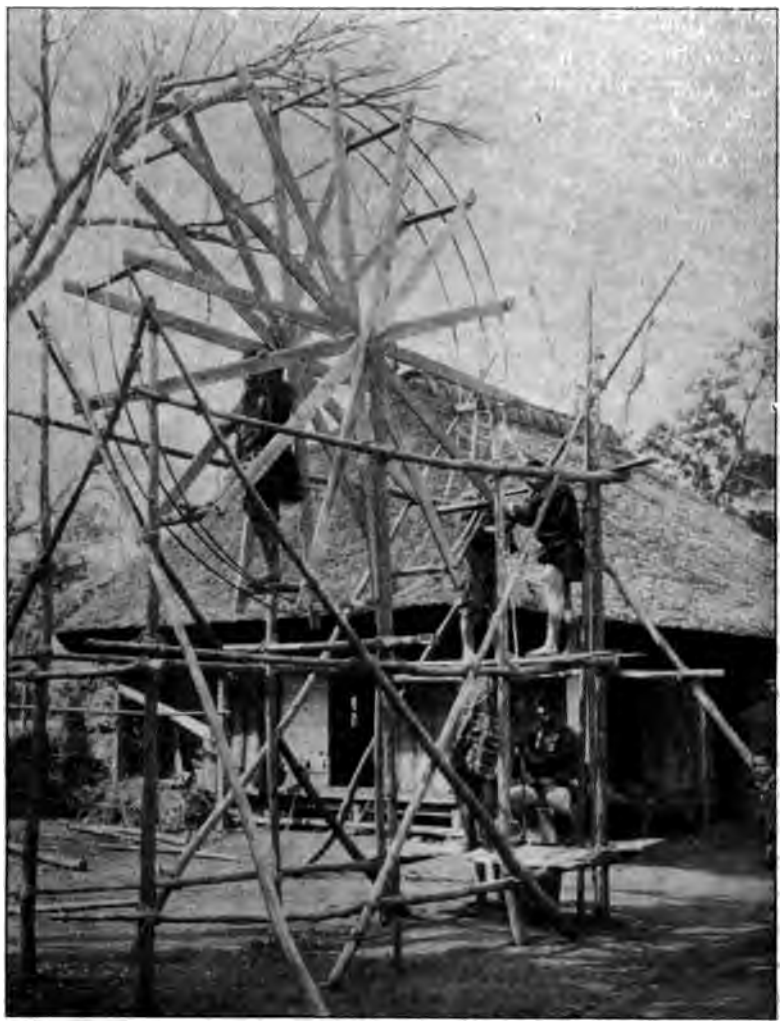


FIG. 2.—WINDING THE REEL.

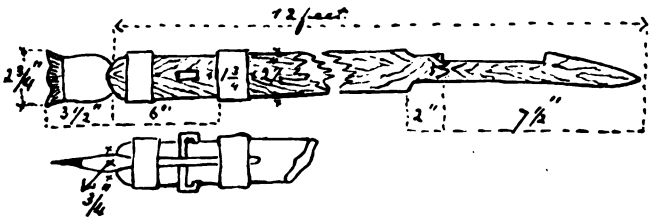
of bamboo strips are then passed around the reel and over the cross-bars, one at each side of the reel, and firmly tied to the cross-bars.

A shallow trench is then dug within the space covered by the scaffolding, and immediately below the reel: and if the soil be very soft, the hole must be lined with matting, and an outlet-channel must be provided to carry off all the water and pulpy débris that will, later on, be removed from the bore-hole, from time to time. A narrow spade, gouge-like in form, some 6 inches across, and with a long wooden handle, is used to dig a hole to a depth of from 8 to 12 feet, and a sufficiently long hollow bamboo or wooden cylinder, not less than 4 inches across the hollow, is inserted therein, great care being taken that it shall go down and rest plumb or perpendicular. About 1 foot of the cylinder will remain above ground, and over it and surrounding it is placed a bottomless tube or box, some 18 inches across. The boss of the well-sinkers then seats himself on a stool opposite this box and well over it, his feet on opposite sides, and facing the reel and scaffolding, as shown in Fig. 1. From this position he issues his orders and directions, all the while keeping his hand on the topmost strip of bamboo, one of the number forming the connecting-rod or chain attached to the tools used for mashing up or removing the soil and rods down in the bore-hole. The jar conveyed to his arm upon impact with the bottom of the bore-hole tells him exactly the nature of the substance composing the stratum then being worked upon.

The method of working is for the gangmen to arrange themselves in two or more tiers on the scaffolding, in such a manner as to enable them to handle the connecting-rod to the best advantage: lifting it up about 1 foot or 1½ feet each time, and then letting it down by slackening their lifting muscles. The weight of the cutting or mashing-tool and of the connecting-rod is generally sufficient to make the required impression on the material of the stratum at the bottom of the bore-hole; but should extra force be required, the boss alone will give it by a strong downward push or blow. Such extra force is seldom necessary, and is avoided as much as possible, for it is liable to cause the couplings connecting the sections of the connecting-rods to loosen and perhaps part. While this jumping or ramming operation is in progress, the boy, in attendance, will every now and then pour a few buckets of water down the bore-hole. In sandy and porous soil, this water should be of the consistency of thick pea-soup, made so by having had a quantity of clay mixed with it.

The water is used in order to soften the material of the rock, etc., down below somewhat, and so help to reduce it to a pulp, the clay to form a waterproof coating on the sides of the bore-hole, and thus prevent surface and underground waters from draining into it.

*Chisels.*—The cutting- or boring-tools are of two kinds, one for soft rocks, clay, gravel, etc., and the other for hard rocks. The first is an iron or steel chisel fixed into a shaft of hard wood, (Figs. 3 and 4). The second is a bar of steel, 2 to 3 inches thick—




FIGS. 3 AND 4.—CHISEL FOR CLAY, GRAVEL, ETC.

a crow-bar in fact. Should it be found necessary to use this steel-bar, it is not attached direct to the bamboo connecting-rod, because the hardness of the metal combined with the very distinct and direct jar, conveyed upon impact with the hard rocks below, is too much for the bamboo, causing it to split after a time; consequently, a connecting-bar or link of hard wood (Fig. 5) is inter-

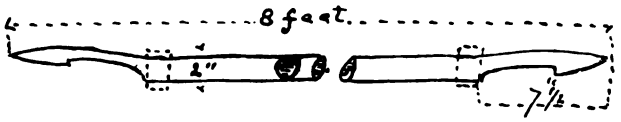



FIG. 5.—CONNECTING BAR.

posed between the two. The wood most commonly used here for this purpose is *keyaki* or Japanese teak (*Zelkewa acuminata*). The method of coupling the two together is shown by Fig. 6, bamboo-wedges being driven in under the iron-rings in order to tighten and prevent them from slipping.

FIG. 6.—COUPLING.

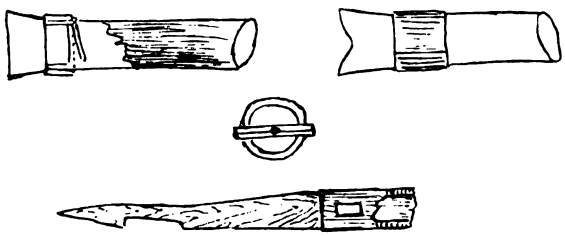
The wooden connecting-rod, in its turn, is coupled to the bamboo-rods in the manner shown in Fig. 7. The first or bottom

bamboo-rod has attached to it a short length (15 to 18 inches) of wooden coupling.

*Sludger.*—The next tool is the pipe or tube used for removing the pulpy débris from the bottom of the bore-hole. It is an iron-tube, 3 inches in diameter and about 8 feet long. At its bottom end, it is screwed on to a short length of another and larger piece

FIG. 7.—COUPLING OF WOODEN CONNECTING-ROD TO BAMBOO-RODS.

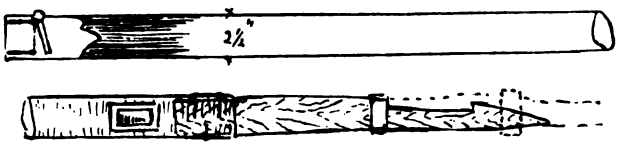
of iron tubing expanding outward—bell-shape wise. Across it and in it, and slightly projecting downward from it, is fitted a steel chisel or chopper, wherewith to separate and prevent the débris from balling, so that it may enter up the tube without difficulty, when the tube is let down upon it in a succession of short rams or downward strokes. Immediately above the chisel is fixed a valve, opening upward, so that while the débris can enter up the tube, it cannot well fall out. The tube, or sludger, is shewn in Figs. 8, 9, 10 and 11; and a very suitable tube can be made from a



FIGS. 8, 9, 10 AND 11.—SLUDGER.

common iron gas- or water-pipe. When the boss well-sinker concludes that enough débris has entered the tube, he gives the order to lift; and the way in which this is effected will be described later. Some 5 feet up the tube is an oblong hole, 3 inches long and 1½ inches wide; this serves the double purpose of allowing the air and water to escape; and, upon the tube reaching the surface, permits the workers to empty it with ease by simply turning it upside down. At the upper end of the tube and extending to the aperture, a bar or rod of wood is inserted and fastened to the tube by rivets, and the outward end is provided with a coupling-connection similar to that shown in Fig. 7.

Should an excess of water be collected in the bore-hole, it is removed by a tool (Figs. 12 and 13) similar in many respects to the tool above-described. It can be made of lighter metal, boiler-iron being strong enough, and it is not necessary to attach a chisel to it.




FIGS. 12 AND 13.—WATER-TUBE AND COUPLING.

*Rods.*—The bamboo-cable, chain-links, or connecting-rods are nothing more nor less than long strips of bamboo, from 10 to 12 or even more feet in length, 1½ inches wide and from ¼ to ½ inch thick. The method of joining them on to each other is simple in the extreme, and can easily be seen by reference to Fig. 14. The writer must, however, point out that all the obtruding ends of the wedges are, in practice, pared off as neatly as possible. This bamboo-cable is extremely strong and supple, and yet retains sufficient stiffness to permit of an effective downward stroke being given should the boss consider it necessary so to do. It can be easily wound around the reel or drum, and there is absolutely no danger of its kinking. The winding-up operation is as novel as it is effective:—When the boss thinks that it is time to lift out from the bore-hole the rammer or the emptying tube, he gives an order to the men above him to "hold on a bit." The ramming being stopped, one of the men then steps into the reel and commences to tread it round and round with his feet, by stepping from rung to rung or cross-bar to cross-bar, using his hands on the side planks both to steady and to help himself at his tread-mill work. Fig. 2 gives a very good idea of how this tread-mill work is carried on, and also of the position of the gang when ramming. Should anyone of the bamboo connecting-rods show signs of weakening, it can easily be removed, without interfering with the couplings of the others, excepting only the two at each end of it, and another one is put in to take its place, not more than

FIG. 14.—COUPLING OF CONNECTING-RODS.

from 2 to 3 minutes being required to complete so simple a job. The well-sinkers are very particular in examining every rod and joint when winding up, the boss first, and then the workmen in the scaffolding above him, and in consequence of this care accidents seldom happen.

*Casing.*—When the water-bearing strata are tapped and all the débris removed out of the bore-hole, the well-sinker inserts into it a series of bamboos joined together, making thus a pipe of sufficient length to line the entire depth of the bore-hole. Perhaps this bamboo-piping would hardly be necessary in very firm or rocky soil, but it is used in Chiba-ken, because little or no rock is met with even when boring to a depth of 720 feet or more. It is much more enduring than the writer could have believed possible, 30 years being reckoned a fair average life for it and for the wells. With infinite pains and trouble a party of

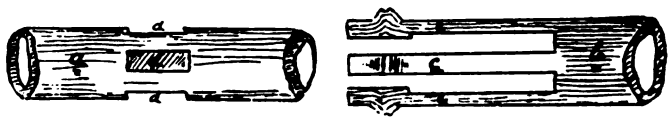


FIG. 15.—METHOD OF CONNECTING THE BAMBOO CASING.

well-sinkers, in the writer's presence, drew from an old well, and from a depth of about 50 feet, a piece of bamboo piping. The term "vegetable" could no longer have been applied to it, for it was nothing more or less than stone. The writer has no idea to what underground depths white ants will carry their depredations, or whether they could or could not attack a somewhat leaky bamboo pipe, with a constant steam of water flowing through it. In the first case, it would be easy enough to circumvent them by using a few lengths of iron pipe at the surface. The bamboo used for this purpose must be freshly cut, that is, green, and of not less than four years' growth; and the lengths must all be as nearly as possible of the same size, those most commonly used being from 2 to 4 inches in internal diameter. The method of joining together the various sections of the bamboo-piping is wonderfully simple, efficacious and expeditious: that is to say, when one has learnt how to do it, and yet it is rather difficult to describe. The first thing to be done, however, is to so arrange the bamboo that the ends to be joined shall be as nearly as possible of the same size. Then these opposite ends are prepared as shewn in Fig. 15;

the end of *a* is inserted into *b*, and the catches *c* are placed in the apertures *d*, and pressed well home. One or two layers of coarse fibrous paper are then tightly wrapped around the joint, and over this is wrapped some stout string made from the fibre of the palm-tree. If this be done properly, the joint will be the last place, in the pipe, to break or give away.

*Water-calling.*—Perhaps, and though the water-bearing strata may have been tapped, the water will not come to the surface. Should this happen, then a tube similar in many respects to that shown in Figs. 12 and 13 will be used; it is, however, smaller and lighter, being not more than from 1 to 1½ inches in diameter. Thin boiler-iron, zinc-sheets or even stout tin-plates are the materials most commonly used for making these tubes. Translated into English, these tubes are called "water-callers" or "water-decoyers;" and, as their names signify, they are used for coaxing the water to the surface. This operation is a remarkably pretty one, requiring great delicacy of touch on the part of the operator, and is conducted as follows:—After the piping in the bore-hole has been cleared of all débris, the water-caller, attached to the bamboo connecting-rods in the usual way, is inserted carefully and slowly, and upon reaching the water it is pushed down a little way into it, and then lifted a little. If this pumping-like operation be done correctly, and kept up for a sufficient length of time, the water will be gradually and slowly coaxed to the surface.

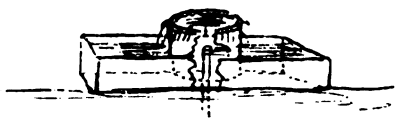


FIG. 16.—WATER-TANK.

*Tanks.*—This having been accomplished, the scaffolding, etc., will be removed, and should the water be required for drinking and household purposes and the like, two troughs or basins will be built around the head of the well, the one inside the other and higher: Fig. 16 is a very common form. On the other hand, should the water be only required for irrigation-purposes, a trough or tank may or may not be built around the head of the well; but usually only a box, not unlike a dwarfed postal pillar-box, will be placed over the projecting end of the bamboo-piping: the water escaping thence, through holes cut under the roof or lid, and spreading itself gradually all over the paddy-field. Should the water, however, be required to be carried some little distance,

this is done in a very similar manner to that in vogue in India: but, at times, bamboo-piping is used for this purpose, especially if the distance be somewhat great.

*Accidents in Boring.*—Despite all precautions, accidents do occasionally occur, and perhaps the most serious of all is the breaking or parting of a connecting-rod, joint, or tool, in the bore-hole. But although this may happen at a depth of 500 feet or more, the chances are that the severed portions will be ultimately recovered, and the work continued, as if nothing particular had happened. The tool or instrument used for recovering severed articles out of the bore-hole is a wonderfully simple contrivance (Fig. 17). It is a sort of "grasping-grapnel," made of steel or iron, and with a heavy iron ring encircling the graspers, which are barbed, the barbs pointing inward. This grasping-grapnel is fastened to the bamboo connecting-rods (Fig. 17), but, before being inserted in the bore-hole, the ends of the graspers are brought somewhat close together by means of a piece of string—not too strong. The same piece of string also ties up the ring to about where the joint of the bamboo is shown in Fig. 17. The

FIG. 17.—GRAPNEL.

idea of tying up the ends of the graspers is that they shall not splay outward and perchance catch in the sides of the bore-hole when the grapnel is being lowered; and the iron ring is tied up in order that it shall not slip down too prematurely. Having satisfied himself that all is in order, the boss inserts the grasping-grapnel into the bore-hole and gives the order to lower away. Upon getting into touch with the severed article, he will make gentle prods at it, until he thinks that it has become engaged between the graspers, then he will give strong downward strokes or pushes, and, although all this may have to be repeated over and over again, it is seldom that he has to abandon the job as an impossible task. The strong downward strokes or pushes cause the string encircling the graspers to break or give way, the

graspers to splay outward and to allow the severed article to go well home between them, and the breaking of the string holding the iron ring permits it to fall and clinch the graspers tightly upon the thing to be lifted. When the boss thinks that a firm grip has been obtained he gives the order to " haul " or " wind up."

*Tools.* — " Accidents will happen," and boring-tools, connecting-rods, etc., will wear out. Such being the case, the well-sinkers must have ever ready at hand certain carpentering and auxiliary tools. These are not many, nor are they very costly, indeed the writer cannot see how they can be much simpler than they are. A glance at Fig. 18 will show what they are like:—No. 1. This tool is used for breaking away knots in the interior of the bamboo, and smoothing off all the rough edges. No. 2. This saw, like most Japanese saws, has two edges, one finer than the other. Nos. 3 and 5 represent very fine saws, used when bamboo pipe-joints have to be made, and for cutting off the obstructing ends of wedges driven under the holding rings, over joints. No. 4. This is a sharp and heavy-bladed knife used for trimming purposes. No. 6. This chisel is used in making the bamboo pipe-joints. No. 7. This is a somewhat sickle-shaped knife used for splitting and trimming bamboo. No. 8. This iron hook or catch is always attached to the scaffolding, and is hooked into the mouth of the emptying-tube, when it is about to be emptied of débris from the bore-hole. No. 9. This iron hammer is used for driving in the wedges, etc. No. 10. This cone-shaped block of wood is used when great care is required in splitting bamboo.

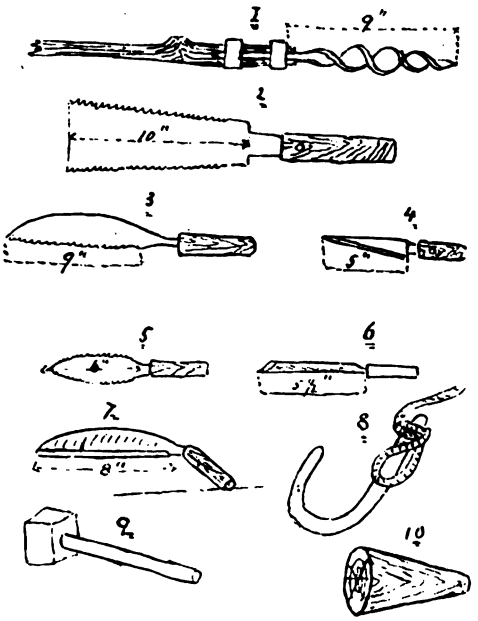



FIG. 18.—TOOLS.

Mr. M. Walton Brown (Newcastle-upon-Tyne) wrote that the Japanese borers, by the addition of clay to water, had anticipated the Honigmann method of sustaining the sides of bore-holes and sinking shafts in sandy and porous soil.* He suggested that the operation of "water-calling" washed the clay from the sides of the bore-hole, and allowed the water to rise to the surface.

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## DISCUSSION OF MR. HAMILTON C. DICKSON'S PAPER ON THE "CRUCIBLE-ASSAYING OF GOLD-ORES."†

Mr. Hamilton C. Dickson wrote that a few errors had escaped correction in the printing of his paper:—Page 673, line 12 should read "the lower level samples;" page 674, line 27 should read "as representative of its bit of reef;" page 681, line 34 should read "the difficulty of estimating the peroxidation of the ore, repeat-assays may be necessary rather frequently, as small buttons must be rejected;" page 688, line 20 should read "mill-samples, from the feeders, does not differ;" and page 689, line 29 should read "As the silver in mill-samples may require to be known, the amount introduced."

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* *Trans. Inst. M.E.*, 1897, vol. xiii., page 155.

† *Ibid.*, 1901, vol. xxii., page 673.

# SINKING BY FREEZING.*

By A. GOBERT.†

A detailed description of the sinking, by means of the freezing process, of No. 1 pit of the Auboué iron-mine, in the east of France, the joint work of Mr. C. Cavallier and Mr. A. Daubiné, has directed attention to a serious drawback in the system at present employed for freezing strata.‡ This consists in the stoppage of the flow of the uncongealable liquid in one or more of the freezing-tubes, and the difficulty with which the stoppage is ascertained.

Messrs. Cavallier and Daubiné state that:—

In order to freeze the strata around a sinking shaft, the solution of calcium chloride, cooled by means of the refrigerators, is placed, so to say, in contact with the strata, by circulating through a system of vertical tubes, comprising inner and outer tubes.

The inner tubes, at their upper ends, are connected to the distributing-ring, which receives the calcium-chloride solution from the refrigerators. The annular spaces separating a pair of concentric vertical tubes are joined, at their upper ends, to the second or return-ring, which receives the entire return-flow of calcium-chloride solution.

A pump, interposed in the circuit, draws the cooled liquid at the base of the refrigerators, forces it into the inner tubes, and causes it to ascend through the annular spaces between the inner and outer tubes. The cold brine becomes warmed on contact with the strata, and then flows anew into the refrigerator, thus performing a complete cycle.

Therefore, each column of the freezing-tubes is connected, one, the inner tubes, with the distributing-ring; and the other, the outer tubes, with the return-ring. At the Auboué pit, these rings consisted of steel tubes, joined to the freezing-tubes by means of leaden pipes fitted with stopcocks, which allowed of the closing of each column, when required.

After the lapse of a certain interval, the temperature of the outside atmosphere having fallen below 32° Fahr., it became very difficult to ascertain whether the liquid was continuing to flow through the tubes. As a rule, the stoppage of flow can be perceived when the head of the tube ceases to be covered with ice. But when the atmospheric temperature is low enough, all

* *Annales des Travaux Publics de Belgique*, 1902, second series, vol. vii., page 45.

† Translated by Mr. L. L. Belinfante, M.Sc.

‡ *Annales des Mines*, 1900, vol. xviii., page 379.

the tubes are mantled with ice, even if the calcium-chloride solution has ceased to flow in some of them. Thus, at a depth of 335 feet, tubes were found wherein no liquid was flowing, although in the shaft, the heads of the tubes were covered with ice. After withdrawing and cleaning the column of inner tubes the flow of liquid was again set going; but, at the bottom of the shaft. the hoar frost or ice only formed on the tubes three days after the recommencement of operations, thus proving that the neighbouring strata had become warmed up again by a not particularly recent stoppage of the flow of the calcium-chloride solution.

Therefore, it would be decidedly advantageous to arrange in each borehole a distinct return-flow of the brine emptying into the refrigerator. This would also allow of uniform regulation of the flow of brine through the tubes, impossible in the case of using (as at present) distributing and return-rings.*

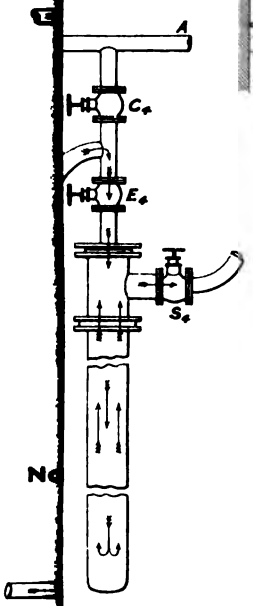
The foregoing lucid explanation indicates that the system at present in use involves the double disadvantage of unequal flow and no flow of the brine, and further, such occurrences cannot be ascertained until the moment when, sinking through the frozen strata, one approaches the freezing-tube that has ceased to perform its duty (or at any rate performs it less efficiently than the others).

In order to obviate these disadvantages, the writer has proposed the arrangement illustrated in Figs. 1 and 2 (Plate XXXIV.). The brine or uncongealable liquid, after flowing through the first freezing-tube, is brought into the second freezing-tube; after flowing through this one, it is led into a third, and so forth. After having, thus, flowed through any given number of freezing-tubes, the brine is led into the return-pipe, which conveys it back to the refrigerator. In this manner, for every unit of time an equal quantity of brine flows through each freezing-tube; and, if the flow were stopped in a tube, it would simultaneously stop in all of them. The stoppage would be perceived at once, because the brine would cease to flow back into the refrigerator.

Fig. 3 (Plate XXXIV.) shows the arrangement which should be used, if it be desired to reserve the power of isolating one or more of the freezing-tubes, without stopping the circulation in the other tubes. The arrows indicate the course followed by the stream of brine from No. 1 to Nos. 3 and 4 tubes, when No. 2 tube is isolated.

Figs. 4 and 5 (Plate XXXIV.) illustrate an arrangement which allows of ascertaining the temperature of the brine at its entry

* *Annales des Mines*, 1900, vol. xviii., pages 420, 422 and 423.




No. 4 Tube.

Fig. 6.—Section.

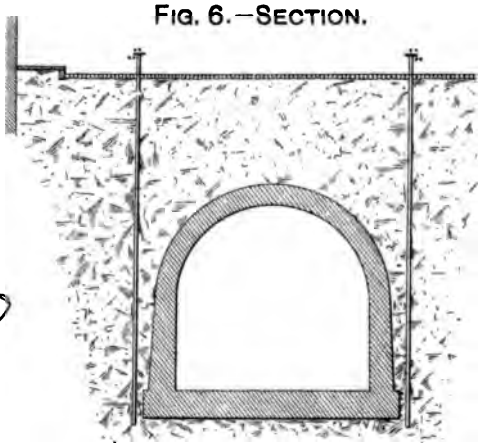
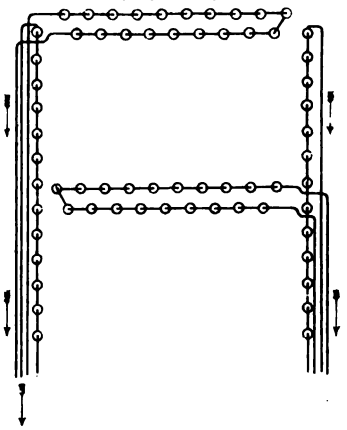


Fig. 7.—Plan.



—Section.

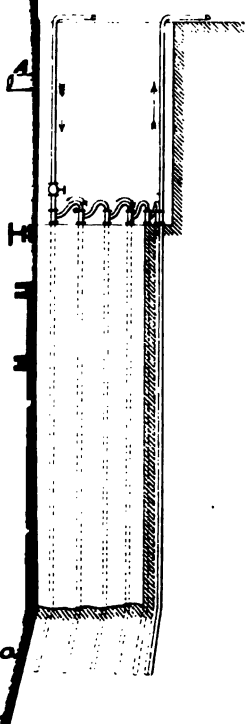
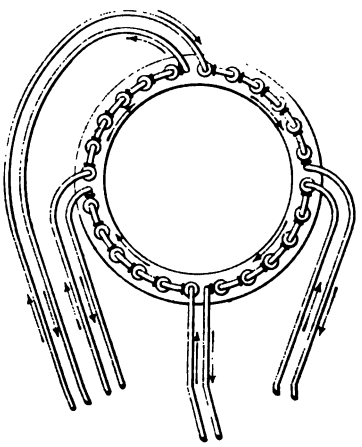
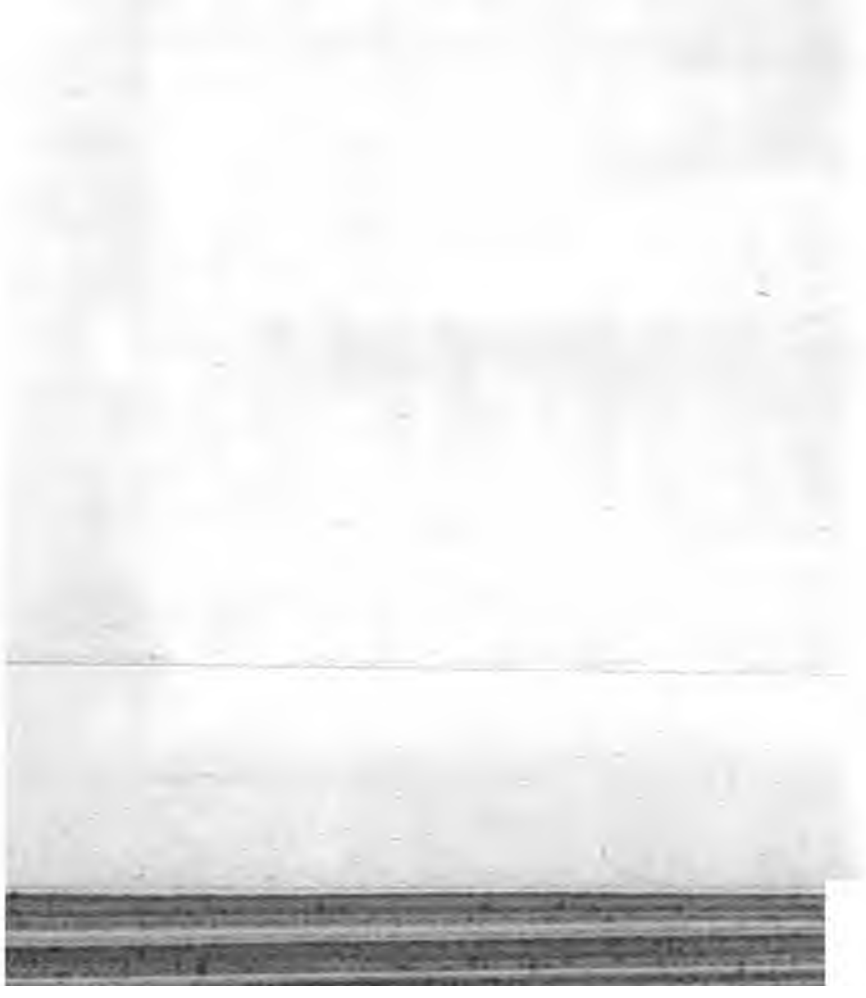



Fig. 9.—Plan.



And^w Reid & Comp^y L.^d Newcastle on Tyne.



into, and egress from, each freezing-tube. If the data supplied by the thermometers be noted, and the quantity of brine flowing through each tube be taken into account, it will be an easy matter to calculate how much heat has been absorbed from the strata by each tube, and thus one can follow, step by step, the progress of the freezing-operations.

It is obvious that the first tube will freeze more energetically than the second, the second more energetically than the third, and so on. This will constitute a considerable advantage in the case of tunnels and cuttings, because in that way those strata will be first frozen which have first to be got rid of.

Figs. 6 and 7 (Plate XXXIV.) illustrate the arrangement of the freezing-apparatus in the case of a tunnel. The apparatus is so arranged as to allow of the simultaneous formation of several shields, in such wise that when the first shield has been completely eliminated in the progress of excavation, a second shield shall ensure complete immunity against the inrush of water or the breakdown of strata. The second shield is not touched until a third has been formed, and so on.

Figs. 8 and 9 (Plate XXXIV.) illustrate the arrangement of the freezing-apparatus in the case of a shaft. It has been already observed that the first freezing-tube acts more energetically than the second, and so on. If it be desired to secure uniformity of thickness in the wall of ice, the following methods are available: —(1) The direction of flow may be changed by causing the brine or uncongealable liquid to enter the annular space of the last freezing-tube, and to flow out by the inner tube of the first freezing-tube; or (2) the flow of the solution may be started alternately through each freezing-tube; or (3) the freezing-tubes may be placed at variable distances, in such a manner that the distance between them diminishes in the same ratio as the distance of the freezing-tubes from the source of cold increases.

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Mr. C. Cavallier (Pont-à-Mousson) wrote that the connection of the tubes to the collecting-rings had two disadvantages:—(1) There may be an accident in a tube without its being noticed, and (2), when one suspects an accident and tries to locate it, the search is long and difficult, and might compromise the success of the operation.

The accidents that may occur to a freezing-tube are of two kinds: there may be an obstruction or a leakage. The obstructions are due generally to scales of oxide of iron, produced by the oxidation of the tubes, collecting at the bottom of the freezing-tube, and if the inner tube be not from 8 to 16 inches shorter than the outer one, the bottom of the latter is soon filled, the circulation is first diminished, and then stopped. The obstruction might also be due to materials derived from the joints, projecting inwardly, of the tubes, and carried away by the brine. A piece of waste-material might be forgotten or carried down, but the obstructions are generally produced by oxide of iron.

Leaks constitute another source of accident, and may be due to a blow from a pick or a shot damaging a tube, or when a column is, on account of deviation, pushed back close to its proper position, but in this case it is easily perceived and a collar is at once put round it.

The most dangerous leaks are those which are produced by the normal ruptures of tubes, due to contraction. Several instances have occurred, and he (Mr. Cavallier) attributed the rupture to the upper portion and lower portion of the strata freezing before the central part of the columns had frozen. As soon as the central part began to freeze, the tube being held fast at the bottom and top, rupture was produced.

These ruptures may have very serious consequences, on account of the brine escaping, and this interferes greatly with the external freezing, or if freezing has already taken place, it immediately produces a thawing of the strata.

The Gobert system, which consists of grouping the tubes in series of three, for example, is evidently an improvement (Figs. 8 and 9, Plate XXXIV.). It might be said against it that the freezing liquid will produce more cold in the first tube than in the second, and more in the second than in the third, and that the diameters of the cylinders of ice will not be equal, but this objection may be overcome by the direction of the flow of the brine being changed, so that it may flow for 24 hours first through the tube A, then into B, and finally into C; and during the next 24 hours go back through C into B, and finally into tube A.

The method of using the thermometers (Fig. 4, Plate XXXIV.) is very ingenious; and although some might be broken, this does not constitute a reason against adopting a system of this kind.

The arrangement (Fig. 3, Plate XXXIV.) allowing any tube to be isolated when desired, by means of valves, is also interesting. At the Auboué mine, each tube could be isolated for repairs, for examination, and for testing by the hydraulic press when a leak was suspected; but whilst having a high opinion of the improvements that Mr. Gobert had designed, he thought that a more radical method would be preferable. If he had to sink another shaft by freezing he would use a single pump and a single brine-distributing pipe with a series of valves to isolate each tube: and the brine would return separately into the refrigerator—that is to say, he would dispense with the return or collecting-ring, and would have as many return pipes as there are freezing-tubes. In this way, whenever the current was not what it should be, he could immediately conclude either that the liquid was leaking into the ground owing to a rupture of the column, or that the latter was obstructed. In either case, he would isolate the suspected tube, he would withdraw the inner tube, and filling the column to the top, he would see whether the liquid descends, which indicates a leak; or if it be immovable, it indicates an obstruction.

In the freezing process, everything depends upon the verticality of the tubes, that is, upon the verticality of the bore-holes. At the Auboué mine, they bored to a depth of 460 feet: since then, at Bernissard, a shaft had been sunk to a depth of 750 or 800 feet by the same method, which already constituted considerable progress. There are districts where one might be compelled to sink shafts traversing 1,250 to 1,600 feet of water-bearing strata. Would it be possible to obtain a sufficient degree of verticality of the bore-holes? Would it be necessary to sink the shaft in two freezing operations? Would it be possible to make around the shaft two rows of bore-holes, and consequently two rows of freezing-tubes to compensate for possible deviations? He (Mr. Cavallier) was not prepared to answer these questions off hand, but he must admit that it was really a marvellous process, which struck him very much when he saw it for the first time at Lens.*

* *Trans. Inst. M.E.*, 1891, vol. ii., page 441; and 1892, vol. iii., page 1023.

## GRAND JUNCTION WATER-WORKS COMPANY: HAMPTON WATER-WORKS.

The water-works are situated in Hampton and sundry parishes of the county of Middlesex, on the north side of the Thames, and have a total area of about 57 acres.

*Intakes from Thames.*—The old intake, constructed in 1853, is situated opposite Platts Eyot, about ¼ mile above Hampton Church, and consists of two pipes, 36 inches in diameter, and sluices protected by an iron-grating. These deliver water from the river direct into the low-level filters, for the supply of the Country District, and to the Bull engines, which are now used as spare engines upon emergencies. The new intake is situated about 1 mile higher up the river, upon an islet opposite Kenton Court, where a chamber, connected by sluices and protected by a grating, has been built and is connected by pipes, 30 inches in diameter, to a chamber situated on the northern bank of the river. The top of both chambers is raised to a level above the height of the highest-recorded flood. From this second chamber, the water is conveyed by two pipes, 36 inches in diameter, laid under the Lower Sunbury road, to the sluices of the low-level pumping-engines about ½ mile distant.

Under a 10 acres field, immediately opposite the new intake, but upon the north side of the Lower Sunbury road, the gravel-beds form a natural filter, through which the water is drawn by drain-pipes, 24 inches in diameter, with open joints, connected to a third line of pipes, 30 inches in diameter, along the Lower Sunbury road to the works.

*Storage- or Subsidence-reservoir.*—The storage-reservoir, with an area of 10 acres, is 22 feet deep, and has a capacity of 45,000,000 gallons. The top-water level is 29 feet above Ordnance-datum level, and it commands the whole of the filter-beds on the station. With a view to using it regularly as a subsidence-reservoir, and thereby lessening the work of the filters, two water-towers have been constructed, provided with sluices, so that the water may be always drawn off from the surface, at any level.

*Filter-beds.*—The total area of the filter-beds, at Hampton, is 15¾ acres. They are all of modern construction, and capable of delivering the water in excellent condition.

*Pumping-engines.*—At the lower works, two compound condensing Riedler low-lift engines pump the water from the reservoir through the filters or into the subsidence-reservoir. These engines have a capacity of 14,000,000 gallons in 24 hours. A compound-condensing expansion centrifugal pumping-engine, capable of pumping 11,000,000 gallons in 24 hours, is also available for delivering water from the reservoir to the filters; while, for the same purpose, two horizontal expansion condensing engines with three-throw pumps are fixed in an adjacent engine-house, and are capable of delivering 10,000,000 gallons *per diem*.

For pumping the water from the Hampton works to Kew Bridge works, the following engines are available:—(1) Two compound condensing Riedler high-lift engines of a capacity of 14,000,000 gallons *per diem;* (2) a triple-expansion condensing Worthington engine, of a capacity of 3,500,000 gallons *per diem;* and (3) a pumping-engine of the same construction capable of pumping 7,000,000 gallons in 24 hours.

The steam for these pumping-engines is provided by 9 Lancashire boilers, each 30 feet long by 7½ feet in diameter, working at a pressure of 100 pounds per square inch; and by 3 Cornish boilers, each 20¼ feet long by 5 feet in diameter, at a working-pressure of 40 pounds per square inch. At the eastern end of the upper works, 3 Bull engines are also available for pumping 22,000,000 gallons for delivery to Kew Bridge, when required. The steam for these engines is provided by 4 Cornish boilers, 28 feet long by 7 feet in diameter, at a working-pressure of 40 pounds per square inch.

The water for the supply of the Town District is partly filtered at Kew Bridge works, whence it is pumped under a head of 184 feet above Ordnance-datum level into the Town District. The Country District, lying between Hampton and Kew Bridge, is supplied by the following engines:—(1) A Davey compound condensing engine, capable of delivering 3,000,000 gallons in 24 hours: with 3 Lancashire boilers, 26 feet long by 6¾ feet in diameter: (2) two compound condensing beam-engines, capable of delivering 8,000,000 gallons in 24 hours: with 4 Lancashire boilers, each 28 feet long and 8¼ feet in diameter, working at a

pressure of 60 pounds per square inch; and (3) a triple-expansion vertical engine of a delivery-capacity of 5,000,000 gallons: steam being supplied by 2 Babcock-and-Wilcox boilers, working at a pressure of 160 pounds per square inch.

The water delivered to the consumers is subject to daily tests by chemists and bacteriologists; and these reports bear testimony to the excellent quality of the water supplied. These results are further justified by the excellent health-statistics of the districts supplied by the company.

## THE WORKS OF THE SOUTHWARK AND VAUXHALL WATER COMPANY.

The spacious and well-proportioned engine-house, erected in continuation of the older buildings, contains the latest addition to the pumping-plant in the shape of three triple-expansion engines of the marine inverted type, each capable of lifting 9,000,000 gallons of water *per diem* under a head of 280 feet. Their cylinders are 20, 33 and 56 inches in diameter respectively, with 5 feet stroke. There are two flywheels, one at either end of the engine, and in ordinary working they make 25 revolutions a minute. Each engine operates three double-acting pumps, 16½ inches in diameter and 5 feet stroke. They were designed by the company's engineer, Mr. J. W. Restler, and were made by the North-eastern Marine Engineering Company, Limited, Sunderland.

The steam required for driving these engines is generated in a roomy and well-lighted boiler-house, adjacent to the engine-house. It is fitted with two sets of Babcock-and-Wilcox tubular boilers (five boilers and an economizer in each set), working at a pressure of 200 pounds per square inch. The engine-house is lighted by means of electricity, generated by a small engine, designed by Mr. Restler, coupled to a direct-current dynamo. Arc lamps are employed.

In an engine-house forming part of the original buildings, there is a set of Cornish engines which have been working since 1854. The steam for the original portion of the pumping-plant was furnished by a long range of boilers.

There are two compound engines by Messrs. Moreland & Son,

bearing the date of 1886, working with a boiler-pressure of 100 pounds per square inch. These representatives of what was, at the time of their erection, an advanced stage of engine-construction, are still doing high duty.

The company possess altogether, at their various stations, 28 pumping-engines, of a total of 6,200 horsepower. From Hampton, they can pump 16,000,000 gallons of water daily to Battersea for filtration-purposes, and 36,000,000 gallons of filtered water to other parts of their district.

There are, in all, 31 filter-beds, covering an area of 31¾ acres. At Hampton, there are now three sets—the first consisting of 9, the second of 7, and the third of 6 beds. The first set, somewhat irregular in shape, occupies ground immediately adjacent to the engine-houses; the second, practically square or triangular, adjoins the small reservoir on the river-bank; and the third set occupies the easternmost portion of a tract of land, rather more than 0·3 mile in extent, which is surrounded on three of its sides by the works of the Grand Junction Water Company. Here there is room for 8 more beds. The most recently-formed filter-beds are oblong in shape, and down the centre of each is a long bricked channel, into which the water is admitted. When this is full, the water flows over the edges on to the sand lying upon the bottom of the filter. The whole process is so gradual that no disturbance of the sand takes place. Facilities are, of course, afforded for taking samples of the water for purposes of examination.

Farther west, and extending northward, are two large storage-reservoirs, having a combined capacity of 300,000,000 gallons. Away to the north-west, and distant about ¼ mile, is situated the distributing-reservoir for the Staines Reservoirs Joint Committee. The small reservoir on the river-bank has a capacity of 90,000,000 gallons. The two reservoirs at Hampton, in conjunction with those at the Battersea station, furnish storage for 436,000,000 gallons; and there are covered reservoirs for filtered water equal to 19,000,000 gallons, while others for 52,000,000 gallons are in course of construction.

The 300,000,000 gallons reservoir is the largest; but two others, which have been commenced at Walton, will have a combined capacity of 1,167,000,000 gallons. They will have a total top water-area of 123 acres, and the depth of water will be 40 feet. The division-wall will be 180 feet wide at the

bottom, tapering to 12 feet at the top. The top level of the bank will be 70 feet, and the top water-level 15 feet, above Ordnance-datum level. The puddle-wall will be 10 feet wide on the ground-line, tapering to 6 feet at the top of the bank.

The Southwark and Vauxhall Water Company is a combination of two companies, one of which—the Southwark—dates back to 1582. Early in the nineteenth century, the undertaking was furnishing to Southwark water raised by two wheels situated under London Bridge, on the Surrey side. In 1839, a distinct advance was made by constructing works at Battersea, where the intake was situated. In 1845 an amalgamation was effected with the Vauxhall Company, formed in 1804, and thus arose the Southwark and Vauxhall Water Company. In 1852, the intake was removed to Hampton. In 1886, the works were extended; and since then other stations have been established.

The present sources of supply are the Thames and a well at Streatham; while other wells are under construction at Merton Abbey and Honor Oak. The maximum quantity of water which the Company are allowed to draw from the river Thames in one day is 100,000,000 gallons; but the average is 45,000,000 gallons. The well at Streatham produces about 2,500,000 gallons daily.

The storage-capacity will be 1,603,000,000 gallons, exclusive of 71,000,000 gallons of filtered water: making altogether 1,674,000,000 gallons, or sufficient for 58 days' supply, without drawing any water from the Thames. For the distribution of the water, three trunk-mains are employed, with a carrying capacity of 52,000,000 gallons. The pumping power is equal to 78,000,000 gallons daily.

# APPENDICES.

## I.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF COLONIAL AND FOREIGN SOCIETIES AND COLONIAL AND FOREIGN PUBLICATIONS.

### MINING INDUSTRY OF GREECE.

*Das Berg-, Hütten- und Salinenwesen Griechenlands.* By A. CORDELLA. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, 1901, *vol. xlix., pages* 351-382.

The first part of this memoir deals with all known occurrences of useful minerals in the Hellenic kingdom, and the geological and other characteristics of the deposits. The second part is devoted to the statistics of output, and also those of import of fuel, etc., necessary for the treatment of ores and for metallurgy in general. The third part is a historical sketch of the gradual development of mining and metallurgical industry in Greece; a point upon which none can be better qualified to speak than the author, who is a mining-engineer resident in Athens, formerly general manager of the Laurium mines, and personally connected with the industry in that country since 1861. That year was marked by the issue of a mining code, based on French mining legislation; and thenceforward up to 1882, hundreds of concessions were granted. From 1882 to 1891, the Hellenic government stopped any further such grants; between 1891 and 1898, five concessions in all were granted, and then in 1898 the Zaimis ministry granted more than 40, with the intention of promoting mining enterprise. The present government is busied with the preparation of a new mining code, based on Prussian legislation.

The occurrences of gold are of no practical importance. Silver-ores have been worked among the liparite-rocks of Milos. Lead-ores are worked at Mykonos and Siphnos, as well as in Laurium (argentiferous): they are found at many other localities. Zinc-ores are worked in Eubœa, Antiparos, Siphnos and Laurium; workings in other localities have been abandoned. Copper-ores are worked in the Othrys mountains, and exploration-work has been done on them in many other places. Rich iron-ores are worked in Antiparos, Scriphos, Thermia, Siphnos, Skyros and Laurium, also near Athens and Marathon; manganese-ores in Milos, Andros and Laurium, and they have been recently discovered at Othrys and Volos.

Among the serpentines and gabbros, rocks of very widespread occurrence in Greece, chromite is constantly found. In many places, the deposits have been worked out, but mining operations are still in progress at Lamia (ore containing 30 per cent. of oxide of chromium) and Triangli in Thessaly. Rich chrome-iron-ore deposits with magnetite- and copper-ore are stated to occur at Neochori in the Pelion range. The corundum or emery-mines of Naxos are State property, and the right to work them belongs to the communes of

Apiranthia and Koronis: the State pays to these communes about 32s. for every metric ton of emery produced and delivered to its agents. So too the gypsum-quarries on Milos are State property: the mineral is usually purchased for "plastering" the resinous wines of the country.

No workable deposits of rock-salt have been found in Greece as yet, and about 28,000 metric tons yearly are evaporated from sea-water in salt-pans along the coast. This salt is a Government monopoly. The pure dry salt of Milos constitutes an exception: it is got from warm brine-springs.

Brown-coal or lignite is worked in the younger Tertiary deposits of Eubœa, Oropos and Megara. In the first-named island, the rich mines of Kumi are less than 4½ miles distant from the coast, and show seams, from 3½ to 11½ feet thick, extensively developed in the Pliocene beds. The lignite-deposit of Oropos is 23 feet thick. Moreover lignite has been recently discovered near Athens itself, and at Makirkomi, Gardiki, etc.

Native sulphur has been got from weathered porous trachytes at Pherlingos on the eastern side of Milos, for the past 40 years. It occurs in thick bed-like masses, and is treated on the spot in Doppioni ovens.

Greece is extremely rich in statuary and other marble. Both varieties are still being quarried in Paros, and the quarries of Naxos, Skyros, Eubœa, Attica, the Peloponnesus and Thessaly are of considerable industrial importance. It is interesting to note that many of these are worked by English companies.

From the tables of statistics, the inference may be drawn that, while the zinc-production of the country has declined, the output of iron-ore has increased enormously. The decline in zinc is largely attributable to the pinching-out in depth of the great ore-deposits of Kamaresa, and the rich ores of former years, which were wont to yield 60 per cent. of metallic zinc on roasting, are now very scarce. On the other hand, the plumbiferous and manganiferous iron-ores discovered within the last 15 years in the northern and eastern portions of the Laurium mining-field seem likely to furnish a large output for a long time to come.

The modern development and revival of mining industry in Greece may be said to date from the year 1864, when a French company started works at Ergasteria with the view of smelting for lead the materials of the enormous cinder- or slag-heaps left by the ancients around the old silver-mines of Laurium: these slags amounted to more than 1,500,000 tons, containing from 5½ to 14 per cent. of lead and a fair amount of silver. From this it was an easy step to work fresh ore-deposits in the same area, not to speak of the heaps of formerly rejected vein-stuff found round old shafts, etc. (6,700,000 tons containing up to 10 per cent. of lead and 2½ parts per 1,000 of silver).

The geology of the Laurium district may be briefly stated as a succession of micaceous clay-slates and limestones of Cretaceous age overlying crystalline mica-schists and marble. Among these occur the ore-deposits, partly in narrow veins, and partly as "contact-zones." The marble is the "farewell rock" of the metalliferous series, and itself chiefly contains zinc-ores. The hematites of Siphnos, Kythnos and Grammatiko are in the main fissure-veins in limestone: these ores do not continue into the underlying mica-schists.

L. L. B.

## COAL-MINING AND METALLURGICAL INDUSTRIES OF RUSSIA.

*Die Metallurgische und die Kohlen-industrie in Russland.* By E. DAVIDSON. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, 1901, *vol. xlix., pages* 114-176.

The first portion of this exhaustive paper (which is compiled from an official publication issued under the auspices of the Imperial Ministry of Finance) deals with the more recent developments of the iron-industry in Russia. Up to the end of the seventies, mostly foreign materials and machinery, imported duty free, were used in building the railways; but the Government then stepped in, and besides issuing decrees which compelled the railway-companies to give their orders to the hitherto neglected home-producers, itself gave large orders for locomotives, wagons and rails, established premiums for locomotives built entirely of Russian materials, and for steel rails made from Russian ores, and raised the duty on foreign engines and tenders. Nevertheless, the statistics after seven years showed that out of 21,250 miles of railway, only about one-third was laid with "Russian" steel rails, and the greater number of these were made by working up old foreign iron rails: the percentage of genuine home-made steel rails from Russian ores on the Russian railways being only 23·9. To secure this meagre result, the Government had paid away £2,258,612 in premiums.

Meanwhile in Poland, the successive raising of the import duties on foreign pig-iron in 1884, 1885, 1886 and 1887, fostered the growth of the native iron-industry in that portion of the Russian empire. Coal is got in the Sosnowice-Dombrowo basin, and rather poor iron-ores from the provinces of Radom and Kjeletz, coke alone being imported from Silesia on account of the unsuitability of the native coal for coking purposes. Ore is brought from Krivoi Rog in southern Russia to enrich the Polish ores. A brief description is given, with statistics of output, etc., of the principal ironworks, rolling-mills, and engineering shops in western Poland, testifying to the enormous industrial development which has taken place there within the last fifteen years.

But the vast area of the Donetz coal-basin and the rich iron-ore deposits (67 per cent. of metallic iron) of the province of Yekaterinoslav (not to speak of its manganese-ores, limestones, dolomite and refractory earths) seemed to mark out southern Russia as the natural centre of a great iron- and coal-industry. At intervals from 1797 to 1870, the Government made a series of attempts, mainly unsuccessful, to start ironworks on its own account; and then it was decided as a last resource to encourage private enterprise. Between 1870 and the middle of the eighties, only two ironworks existed in southern Russia, belonging to the New Russian Company (founded by a British subject) and Mr. D. A. Pastuchow. The then available supply of iron-ore was too small to permit of continued development of the industry, but the situation was saved by the discovery of new ore-deposits at Krivoi Rog. This discovery was due to the indomitable energy and perseverance of a local landowner, Mr. A. N. Paul. The Russian government and Russian capitalists proving alike sceptical and obdurate, he obtained the help of foreign capital, and from that time may be said to date the vast industrial development which is in process of transforming southern Russia. At present, 29 blast-furnaces are at work, and 12 more are in process of erection: all but 3 or 4 of these are financed by foreign capitalists. The foregoing numbers include only the larger works—there is in addition quite a swarm of small factories, machine-shops and rolling-mills, but no pig-iron is produced at these smaller establishments. With regard to the production of pig-iron in the whole of Russia, that was nearly quintupled

between 1885 and 1898, and among the iron-producing countries of the world, Russia advanced from the seventh place which she occupied in 1887 to the fifth place in 1898, leaving Belgium and Austria-Hungary (once her superiors) far behind. This progress is mainly traceable to western Poland and southern Russia. Elaborate comparative statistics are tabulated of the production of iron and steel in the various districts of the empire, and it is plain that the Ural is not likely to regain its former predominance in that respect (at least as regards steel). About 68·6 per cent. of the total consumption of these metals in Russia is of home production, 31·4 per cent. being imported from foreign countries. Thus, despite the fact that the Russian output has increased more than fivefold since 1870, the demand has outstripped the supply. And yet, calculating according to the number of inhabitants, Russia comes last in the list of great consumers of pig-iron. It is true that prices there remain at a relatively high level: for one thing, the cost of production is greater than in western Europe, and the feverish activity of the demand helps to stiffen the market. In the matter of technical efficiency, the ironworks of southern Russia can challenge comparison with the best of any country.

Compared with other districts, the Urals, despite the fine quality of its ores, is at a disadvantage (1) in the matter of fuel, wood and wood-charcoal being the staple fuel, though it is possible that the use of naphtha may bring about great changes; (2) in the heavy cost of transport and often unsatisfactory means of communication; (3) in want of enterprise and backwardness in technical matters (as, for example, the continued use in many cases of cold blast). It has been pointed out that there are still vast forests which could be made available for fuel, and these would allow of new ironworks being erected in the Urals, but the details given in the paper show that a general "smartening-up" is necessary, in point of technical efficiency, for the metallurgical industry there to have any hope of competing successfully with its rivals elsewhere.

Turning then to the coal-industry, the author remarks that its extraordinary development in southern Russia and western Poland is intimately associated with that of metallurgy in the same areas, it is in fact both a cause and a consequence. From one quarter to one third of the quantity of coal sent off by railway from the Donetz basin is consumed by iron- and steel-works: moreover, 125,000 truck-loads of coal are used annually by similar works established close to the collieries.

The Dombrowo coal-field in Poland has increased its output ninefold within the last 20 years, and the entire coal-production of the Russian Empire increased from 4,504,301 tons in 1886 to 9,167,273 tons in 1896—nearly the whole of this total came from the Dombrowo and Donetz basins. But that, even so, the demand far exceeds the supply may be inferred from the statistics of imports: the importation of coal reached a culminating-point between 1883 and 1885, then sank somewhat till 1893, when it began again to increase, and now overtops the totals of 1883-85. Most of the imported coal comes in by the Baltic ports: importation by the Black Sea appears to be stationary, not to say declining.

A list is given of 15 of the principal collieries of the Donetz basin, with their estimated output for 1899. This represents three-quarters of the total annual output of that coal-field, the remaining 73 smaller collieries accounting for only a quarter of the output. The greater number of the chief collieries belong to foreign capitalists. The amount produced for each workman employed is at present smaller than in western Europe, as the most advanced technical methods are only slowly making their way, in the Donetz at least. In the Dombrowo coal-field technical efficiency is more highly developed, and coal

is being worked at deeper levels. As the smaller concerns are being gradually absorbed into bigger companies, the above-mentioned disadvantage is by way of being overcome. The detailed list of the chief collieries of the Dombrowo basin shows that 9 out of 18 pits are worked by foreign companies, and they account for five-sevenths of the total output of that basin.

The question of cost of production and selling-prices of Russian coal is discussed at some length, and the author then proceeds to consider the future which lies before the metallurgical industry in that country. The latest forecast as to the probable duration of the Krivoi Rog ore-deposits predicts their exhaustion within 27 years, but the author is hopeful that they can be supplemented and ultimately replaced by the ores got from the Donetz basin, from the Kerch Peninsula, from Korsak-Mogila and other localities in southern Russia, and from Transcaucasia. Moreover, by that time, the Ural and the Donetz will be possessed of greater facilities for interchanging coal and iron-ore than at the present day: he considers, for instance, that it will pay to bring by rail into the Donetz the enormously rich ores of Bakal. He dismisses the idea of importing foreign ores as unsuitable to the particular natural conditions of the Russian empire, and claims that with Russian ores alone, other centres of metallurgical industry can be created within the empire besides that of southern Russia. The practical monopoly at present enjoyed by the last-named region is not altogether desirable from the economic standpoint, and foreign capital and enterprise are infusing new life into northern Russia and the Ural. L. L. B.

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## DONETZ COAL-FIELD, RUSSIA.

*Contribution à l'Étude du Bassin houiller du Donetz, Russie méridionale.* By A. FOURET. *Comptes-rendus mensuels des Réunions de la Société de l'Industrie Minérale*, 1901, *pages* 80-83, *and* 3 *plates*.

Geological maps of the Donetz coal-field show as its western boundary a line following a little to the west the railway between Marioupol (a port on the Sea of Azov) and Slaviansk, passing through Jassinovataia, Constantinovka, Droujkovka and Kramatorovka; but the object of the present paper is to show that this boundary may be set back towards the west by nearly 25 miles, thus increasing by about 80 square miles the extent of this vast coal-field, which is now credited with an area of 1,280 square miles. The author calls this addition the Krasnogorovka district from the name of the most important village that occupies its apparent centre.

Explorations made since 1889 have shown that the eastern group of seams continue regularly on the west; and several important seats of working have lately been founded on the west of the railway mentioned above, being connected with it by standard-gauge branches, so that the development of the collieries may be said to have constantly progressed from east to west during the last twenty years. The western group is much disturbed by a large fold, which may be said to cause it to make a right angle with the southern group of which it is, however, undoubtedly the continuation; and this group comprises a great many seams (that are worked at several points) generally occurring at slight depths, the Coal-measures being overlain by a slight cover of sterile rocks.

The number of seams comprising the Donetz coal-field is put at 100; and they contain the whole series of coals from anthracite to lignite. It may be observed generally, though not absolutely, that the coals become more and more

bituminous from west to east; and, indeed, as working has been carried deeper, seams have been encountered affording coal suitable for making gas and blast-furnace coke. Most of the seams are characterized by a low ash-content with a rather high content of sulphur and volatile matter; and, generally speaking, they can all be utilized for industrial purposes. The following table gives a mean of the leading particulars of the coals in the three groups of seams:—

| Group. | Ash. per cent. | Sulphur. per cent. | Coke. per cent. | Volatile Matter per cent. |
|---|---|---|---|---|
| East ... ... ... | 3·25 | 0·92 | 66·09 | 27·46 |
| East-north-east ... | 4·65 | 1·77 | 57·31 | 33·60 |
| West ... ... | 3·86 | 1·93 | 47·20 | 48·90 |

J. W. P.

## COAL-MINING ON THE ISLAND OF SAGHALIEN.

*Der Steinkohlenbergbau auf der Insel Sachalin.* By F. F. KLEYE. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1900, *vol. xlviii., pages* 573-577.

Although the coal-deposits at Due, comprising several 2 to 3 feet seams, have been worked in an irregular manner ever since 1852, the difficulty in the way of obtaining concessions (owing to the attitude of the authorities of the penal settlement), and other causes, have hindered the development of the mining industry until very recently, and it was only in 1899 that the shipments of Due coal attained the amount of 1½ million poods (of 33 pounds).

A second coal-field was opened up in 1891 at Mgatsch, the output from which totalled 800,000 poods in 1899. Two other deposits have been found at the mouth of the river Ssurutura, on the east coast, and between the rivers Sertunai and Noijassi, but are not worked, there being no good harbour at the former place, whilst in the other case the coal-seams are full of gas and faults.

Due coal belongs to the class of sintering coals, and is considered the best coal in the East for forge and factory purposes, but is too full of smalls and too smoky for marine boilers. The heating value (air-dry) is 8,249 calories; and the yield of coke, 65 per cent. Mgatsch coal, on the other hand, is harder and larger, does not sinter, and produces merely a light, greyish smoke. Tests made with this coal in the Russian Pacific fleet shewed that it was good for steam-raising, the flame being regular and of medium length, and the consumption about 20 per cent below Due or Takasima coal, whilst, unlike the latter, there is no corrosion of the fire-brick furnace-linings. The heating power is 7,174 calories; and the percentage of combustible matter 87·93, with 10·2 per cent. of ash, and 1·87 per cent. of moisture. Compared with Cardiff steam-coal, the consumption is as 13 to 10.

In view of the mutually complementary character of Due and Mgatsch coals, the two producing companies have arrived at a working agreement, it being found that a mixture of the two kinds gives a better steam-raising product than either alone, with less smoke, being in fact only about 10 per cent. interior to Cardiff steam-coal. C. S.

## TIN-ORE DEPOSITS IN BOLIVIA.

*L Etain en Bolivie.* *By* MAURICE FROCHET. *Annales des Mines*, 1901, *series* 9, *vol. xix., pages* 186-222.

The present annual output of the Bolivian tin-mines averages 3,000 tons, but it is thought that, if fully worked, with all the necessary plant, etc., they could produce as much as 100,000 tons of *barilla* or crushed ore *per annum*. The recent rise in the price of tin has stimulated the working of the Bolivian deposits to an extent previously unknown, and there are now 35 tin-mines at work in that country. Dearness of fuel, bad roads, the great cost of the upkeep of machinery and the high wages commanded by such workmen as can be trusted to look after the machinery "take the gilt-edge off" the mine-owners' profits. Even then the small margin of profit is still further reduced by taxes and export duties: such is the pitiful picture limned by the mine-owner anxious to obtain special exemptions from the State. Nevertheless the growing demand for tin, due to its extended application in various industries, will make that metal one of the principal sources of the future wealth of Bolivia.

The tin-producing districts are grouped along the western slope of the inland Cordillera, east of the Bolivian plateau, from latitude 16 degrees south to 21 degrees south, over a length of about 300 miles. No such deposits are known in the coastal Cordillera, nor in Peru nor Chile. The district which at present yields the largest output is that of Oruro: the geological conditions are varied in the extreme, and each mine reveals different features, both in that respect and in the matter of quantity and quality of ore. The Huanuni mine is credited with two-thirds of the entire annual production of Bolivia. Here the veins are very irregular and seem to form a sort of stockwork in Mount Poscovi (10,500 feet) and the beds across which they cut are much faulted. In a neighbouring slate-mountain, the principal veins recur, but are there associated with arsenical pyrites.

The mineralization of the veins varies too; while in most cases at depths of 130 and 160 feet the cassiterite gives place to stanniferous pyrites, one of the principal veins which crosses the summit of mount Poscovi, is filled with pure tinstone down to a depth of 650 feet or more. The pyrites is crushed and roasted (the fuel used being *taquia* or lama-dung, with about 20 per cent. of the calorific power of coal), before being washed. Some 9 miles south of Huanuni are the mines of Challa and Apacheta. Here, an extraordinarily thick vein occurs (25 to 30 feet) which can in parts, where pyritiferous, be dug out with a spade. In this neighbourhood, too, are many stream-tin deposits or *veneros*, a few of which have been worked in a rather perfunctory way. About 50 miles north-west of Oruro lies Colquiri, where the Spaniards used to work the silver-ores, but neglected the tin. This is a remark which applies to a great many similar ore-deposits all over Bolivia: the old Spanish workings are plainly seen to have in part exhausted the silver-bearing veins, while the cassiterite-veins close at hand remain untouched to the present day. In the great mountain-massif of Tres Cruces (20,000 feet above sea-level), the Sayaquiri vein is worked; it is 25 feet thick, and the cassiterite of rather poor quality is associated with iron-pyrites and wolfram, sometimes, however, the ore is crystallized and assays to 70 per cent of metallic tin. But these veins are so high up in the mountains that they are covered with snow for a good half of the year, and they are inconveniently far from any streamlet that could be used for washing the ore, etc. The Avicaya mines are very productive and there the country-rock is a compact porphyry. The veins are regular, and the ore is of good quality. The tendency of the cassiterite to pass in depth into stanniferous pyrites is very general in Bolivia.

In the department of La Paz, the mines of Milluni, Huayna Potosi and Chacaltaya are all situated on one ore-belt, some 12 miles in length. The veins appear to be of very recent origin, for they occur very near fossiliferous gypsum-bearing beds and red clays which have been faulted by the disturbances that ridged up the neighbouring Andes. No doubt the same disturbances produced the great fissures now filled with tin, bismuth, iron, silver, lead and zinc-ores, amid slates of Silurian or even pre-Silurian age. At Milluni, out of 15 proved veins, only two or three have been worked up to the present, and at Huayna Potosi, out of a similarly large number, only two veins have been touched. The recent influx of new capital will bring about great changes in this respect.

At Viloca near Araca, rather more than 60 miles from La Paz, some very rich stanniferous veins have been discovered lately. The frequent association of bismuth with the tin-ore seems to be a marked characteristic of these deposits in the department of La Paz.

In the famous district of Potosi, tin is a very common associate of silver. Some mines have been worked for tin, but are now abandoned (Porco, Marangua and Ocuri): yet payable veins, hitherto untouched, are abundant.

The author then describes the treatment to which the ore is subjected in Bolivia to make it available for export. It is sorted, crushed, washed over sieves, etc., until a very concentrated ore is obtained. The methods employed are slow, and involve much manual labour (which is cheap). Of late years, however, improved mechanical arrangements have been introduced, and much machinery has been imported from the United States. Some of the poorer ore is roasted, besides being sorted and washed.

The actual workers in the mines are *cholos* or half-breeds. The native Indians are only employed on such work as befits unskilled labourers or navvies: they are paid 2s. to 2s. 6d. per day of 12 hours, and the women (who wash the ore) 1s. 3d. to 2s. Miners' wages range from 3s. to 4s. 2d. *per diem*. Heavy export-duties are levied on tin (whether in metal bars or in the form of the concentrated ore, *barilla*) and on bismuth, and as they constitute an important item in the Bolivian revenue, it does not appear likely that they will be repealed. The railway from Oruro to Antofagasta on the Pacific coast (but in Chilian territory) being now open, freights are more reasonable than formerly, the present rate being 65s. per ton. To this must be added the cost of bringing the ore by pack-mules or lamas from the mines down to Oruro. In conclusion, it may be interesting to note that Bolivian tin-ores are not directly associated with plutonic granites, but they appear to have some genetic relationship with the thermal springs (holding metallic sulphides in solution) which were the outcome of the Cretaceous and Tertiary volcanic eruptions. L. L. B.

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## MINING AT ROSSLAND, BRITISH COLUMBIA.

*Mining Practice at Rossland, British Columbia: The Methods of Development at War Eagle and Centre Star.* By R. B. BRINSMADE. *Mines and Minerals, (Scranton, Pennsylvania)*, 1901, *vol. xxi., pages* 363-367, *with* 18 *illustrations in the text.*

Mining in Rossland has been in some part carried out by engineers from Butte, Montana, but the different geological and topographical conditions prevalent at Rossland have necessitated a radically different method from that in use at Butte City. The practice followed at the Centre Star and

War Eagle mines is typical of the methods of the camp, and is, in the main, the practice outlined by the writer. The country-rock is a hard igneous formation, mostly diorite, containing the fissure- and shear-veins worked. The strike of the veins is east and west, with a dip to the north of 50 to 70 degrees. The rock is very dense, hard to drill, and tough to break, causing a large bill for drilling and powder; but to compensate, no timbering is required to support the excavations. The values of gold and copper are contained in pyrite, chalcopyrite and pyrrhotite, distributed through the pay-shoots in irregular masses.

The mines have been developed by running inclines along the dip of the vein and from these inclines driving horizontal drifts along the strike at intervals of 125 feet. The stopes vary from 5 to 13 feet in width. The vein-structure is complicated by numerous dykes and faults and the diamond-drill is employed to find the continuation of the vein, as well as to evaluate the ore-bodies when discovered.

Two sizes of diamond-drills are used, one with a bit of $2\frac{1}{8}$ inches outside and $1\frac{3}{8}$ inches core-diameter, and the other with $2\frac{1}{8}$ inches outside and $1\frac{5}{8}$ inch core-diameter. The machines, being seldom used for boring over 300 feet deep, are set on two vertical bars jack-screwed against the rock-walls, and are run by compressed air from the percussion-drill mains. The holes are cored throughout; the core-barrel is 5 feet long, but in careful sampling it is sometimes pulled out for every 6 inches of advance. The drilling-engines are screw-fed, and fitted for 300, 700, and 1,000 revolutions per inch of advance. Their ordinary speed is 300 revolutions per minute. Water is pumped through the drill by a small independent boiler-feed pump run by compressed air. The average progress is 1 foot per hour. When drilling in ore, sludge-samples are taken by running the discharged water into a tin-pail in which the sludge settles out. The Rossland rock is very hard on bits and diamonds; it occupies the time of a skilful bit-setter to keep one drill running and the wear of carbons is somewhat less than $\frac{1}{64}$ carat per foot of hole drilled. Each bit will drill about 12 feet only before re-setting is necessary.

The writer describes the methods of drifting, stoping, raising, etc., employed at Rossland. In a particular case of wide stoping, a large ore-body was attacked in successive sections, the drills were set on tripods, the holes were 5 feet deep, and as many as 100 holes were blasted on the bench at one firing. The square-set method of timbering has been adopted for the wide stopes of the Centre Star mine. This is similar to the system pursued in the wide veins of Butte, with the exception that the timber in Rossland is used as a platform for drilling and loading, and has little or no function as a support of the excavation. X. Y. Z.

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## GOLD-MINES OF OVALLE, CHILE.

*La Minería en Ovalle.* ANON. *Boletin de la Sociedad Nacional de Mineria*, 1901, *series* 3, *vol. xiii., pages* 28-29.

The district of Ovalle forms part of the province of Coquimbo, and lies on the Pacific coast, a few miles south of the estuary of the Limarè. The principal group of ore-bodies is formed by three parallel veins, striking south-east and north-west at intervals of a few feet, and varying in thickness from 23 to 39 inches. There have been worked irregularly down to a depth of 160 feet or so, yielding at that depth 30 parts of gold per million, but there the workings were stopped on account of defective ventilation and the increased cost of labour the deeper down one got. The present owners have

not sufficient capital to work the mines in accordance with modern methods, and they content themselves with taking out of the surface-workings the ore that was not considered good enough by the old miners. The gangue is soft, easily crushed, and contains very little pyrites: the country-rock is slate.

There is, however, a mine about ¼ mile away from those first described, which is regularly worked by means of shafts and galleries, and is the only one so worked in the district. So far they have only gone down to a depth of 200 feet below the surface. The vein is parallel with those of the principal group, and varies in thickness from 30 to 40 inches. A small amalgamation-plant, with a Huntington stamp has been erected here, and power is furnished by means of a Babcock-and-Wilcox tubular boiler. The ore contains, at the depth mentioned, 20 parts of coarse gold per million, which on treatment yields 60 to 65 per cent. of fine gold (of grade 850 to 870). Of the remaining 35 per cent., it is calculated that about three-quarters could be recovered by the MacArthur-Forrest process. The fuel used (a sort of cactus) is cheap and abundant: the cost per horsepower per 24 hours is about 11d. There is a small harbour about 1 mile from the mine, which has already been used for landing machinery. The mine-waters (used for the boiler and for the amalgamation-plant) contain a good many salts in solution; in very rainy seasons the amount of water in the workings becomes inconvenient, but in ordinary seasons the water which has to be dealt with in the mines does not exceed 875 cubic feet *per diem*. Miners' wages average 1s. 10d. a day, *plus* a ration of food of the value of about 4d. Many other veins are being worked in the district, but in so superficial a manner that, although the quartz is rich in gold, they yield very little profit. L. L. B.

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## ZINC-LEAD DEPOSITS OF SOUTH-WEST ARKANSAS.

*The Zinc-lead Deposits of South-west Arkansas.* *By* WM. B. PHILLIPS. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., pages* 431-432.

The zinc-lead mines of Sevier county, Arkansas, are now being developed. The vein appears to be a true fissure in black slate; it is from 3 to 6 feet wide, bears a few degrees east of north, dips northward at 45 degrees, is persistent and strong, and carries more mineral in the lower than in the upper levels. In the neighbourhood, belts of black slate having the same bearing are traceable for miles and form the valleys of the region. At intervals, they are traversed by igneous dykes, and diamond drilling will determine the influence of these upon the nature and occurrence of the ore. There is no present evidence of the faulting of the ore-body. The ore is a mixture of zinc-blende, galena, chalcopyrite and a little pyrite, with willemite and smithsonite sparingly present. The gangue is well crystallized quartz and fragments of slate torn off the walls.

The separation of zinc-blende from the iron-bearing minerals by water classification is a difficult, if not impossible, task. The problem will have to be attacked from another direction and it is thought that the most encouraging outlook is towards roasting and subsequent magnetic separation. The basis of sale of zinc-ore at Joplin is 60 per cent. of zinc and 1 per cent. of iron. For each 1 per cent. of zinc below 60 and for each 1 per cent. of iron above 1, there is a penalty of 4s. 2d. (1 dollar) per ton. It is therefore of the utmost importance that the zinc-ore should be as free from iron as possible. The writer does not know of a more interesting problem in con-

centration, nor one of greater importance, than the separation of iron-bearing minerals from zinc-blende. The results already attained by roasting and magnetic separation are most promising. X. Y. Z.

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## WASHINGTON COUNTY COAL-FIELDS, PENNSYLVANIA.

*Developments in the Washington County Coal-fields, Pennsylvania.* By W. G. IRWIN. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., page* 404.

The Ellsworth Coal Company (an adjunct of the Illinois Steel Company) has within the last two or three years bought 16,000 acres of coal-lands on Pigeon creek, near Bentleysville. Two shafts have already been opened, and the town of Ellsworth founded. All power required is supplied by compressed air and electricity. From the cutting of the coal by machine to the dumping of the coal into railway-cars, there is the greatest economy in all the processes of mining. At the present time, 6 tons of coal per minute can be hoisted from each mine, and the Company will have 9 shafts of this pattern and capacity, and these, when completed, will give an output of 54 tons per minute, or more than 75,000 tons per day of 24 hours.

X. Y. Z.

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## ELECTRIC ROCK-BORING MACHINES AT HALLSTATT, AUSTRIA.

*lektrische Gesteinsdrehbohrmaschinen in Hallstatt.* By C. SCHRAML. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 237-238.

At the Hallstatt salt-mines, experiments are now being made with different types of electric boring-machines, for the selection of one suited to the peculiar strata in the mountainous salt-district of Upper Austria. The chief difficulty is caused by the frequent appearance of larger or smaller masses of very hard anhydrite in the salt-bearing rock, which offer resistance to the thrust of the machine. Three machines are now being tested, a Siemens and Halske, and two from the Union Electric Company. A fourth by Mr. Bornet is also to be tried, his hand-boring machines being already used in these mines.

In the Siemens machine, the electro-motor is coupled direct, instead of transmitting the power through a flexible shaft. The thrust of the borer is regulated by a rope-brake attached to the nut of the spindle, so arranged that by turning a screw the action is adjusted to the nature of the rock to be pierced. A constant current of 1 kilowatt is required, which is sufficient if the rock be not too hard. The machine has been working continuously for nearly a year, driving headings.

In the Union machine (Anger type) the speed of the electro-motor is transmitted to the spindle of the borer by wheels geared 5½ to 1. Variations in the thrust to suit different hardnesses of rock are effected partly by varying automatically the speed of revolution of the motor with varying loads, and partly by an arrangement by which the speed of revolution and the thrust of the borer can be reduced, when passing through very hard rock. This solidly constructed machine has also been working 9 months, and the results, if the rock be not too hard, are satisfactory. For harder rock, especially anhydrous gypsum, it has not always been found sufficiently powerful. The speed of the borer has now been reduced, by making the proportion of the wheels 10 to 1, and this improved type has been successfully driven for two

months, through rock-salt interspersed with tough and very hard anhydrite. The speed of revolution being diminished, the thrust is not so violent, but more steadily maintained than before, and a current of only 2 kilowatts is required. B. D.

## DENSITÉ.

(1) *Explosifs de sûreté. Application de l'Article* 20 *de l'Arrêté royal du* 13 *Decembre*, 1895, *Circulaire ministérielle du* 27 *Octobre*, 1900. *Annales des Mines de Belgique*, 1901, *vol. vi., pages* 182-183.

(2) *Explosifs de sûreté. Densites D et E. Arrêté ministériel du* 28 *Janvier*, 1901. *Annales des Mines de Belgique*, 1901, *vol. vi., page* 184.

The minister has placed the explosives, "Densité D" and "Densité E," on the permitted list, of the following compositions:—

| | Densité D. | Densite E. |
|---|---|---|
| Trinitroluol (*sic*) ... ... | 8·5 | 5·84 |
| Nitrate of Strontium ... | 10·4 | 11·42 |
| Nitrate of Ammonium .. | 81·1 | 82·74 |

J. W. P.

## EXPLOSION OF BLASTING-FUSES IN A MORAVIAN MINE.

*Explosion von Sprengkapseln am Tiefbauschachte bei Mährisch-Ostrau.* By Dr. — Fillunger. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii , pages* 16-17.

A disastrous explosion of blasting-fuses, in which two workmen were killed, took place lately in the Witkowitz coal-mine in Moravia. At 3 p.m., a loud report was heard from the magazine, a vaulted chamber in the mine, about 30 feet long and 10 feet high, and containing 5,000 blasting-fuses, or about 15 pounds of explosives. When an entry was effected, it was found that the iron pillars supporting the roof were blown away, the roof was lifted, and a hole, 1½ feet deep and about 3 feet square, had been made in the cemented floor. The body of one man was found close by, while the other had been blown to pieces by the force of the explosion. Shortly before the disaster, the magazine storekeeper had sent for the carpenter to open one of the chests containing the fuses. Another man, who accompanied him, left the two in the magazine, and had not been gone 2 minutes before he heard the report. The actual time which elapsed was 110 seconds.

The blasting-fuses in this mine are packed in two chests, one within the other, the space between being filled with cotton-wool. Both chests, the outer and the inner, are bolted down with iron screws about 1½ inches long. The capsules are packed in sets of 50 in leaden boxes, and well secured with paper wrappings. Experiments showed that the carpenter could not, in the given time, have loosened the screws of the outer chest, cleared away the paper, and reached the capsules themselves. Therefore, the explosion must have taken place before the inner chest was opened, presumably while it was being opened; hence the body of the unfortunate carpenter, who was in all probability bending over the chest, was blown to pieces. Since the chests could only be opened by loosening the screws, it may further be as umed that it was the turning of a screw in the inner chest which caused the explosion. The inference is that, when the chest was closed down in the factory, one of these screws had been put in crooked, so that the point

projected downwards. As the carpenter gripped it, possibly he inadvertently screwed it slightly further in, and thus caused it to come in contact with the explosive end of a capsule.

This theory was confirmed by the fact that a number of screws, more or less crooked, were found in other chests, and in one or two cases a similar catastrophe was only barely averted. As both of the men had been accustomed for years to handle the chests, the accident could not be attributed to ignorance on their part, nor, in view of the position of the chest in the magazine, could a heavy weight have fallen upon it. Whether the catastrophe really took place under these circumstances or not, it is certain that accidents may happen in this way, so long as the inner chest containing the capsules is bolted with screws 1½ inches long. The writer desires to draw attention to the matter, that some other method of closing these chests may be adopted, and he mentions two other accidents which to his knowledge have occurred, and may probably be ascribed to the same cause. B. D.

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## FIRING BLASTING-CHARGES BY MEANS OF ACCUMULATORS.

*Accumulator-Minenzündung.* *By* JOHANN VON LAUER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1900, *vol. xlviii., pages* 537-539, *and* 1 *plate.*

Recent experiments with the author's accumulator for shot-firing have shewn that, by replacing the old band-conductor with 0·1 inch cable composed of 19 thin copper wires covered with hemp and enclosed in a plaited insulator, the number of shots that can be fired simultaneously is increased to 9 at a distance of 150 feet (50 metres), 5 to 6 at 300 feet (100 metres), and 3 to 4 at 500 feet (150 metres), using platinum glow-igniters connected direct with the cable by iron wires 40 inches long and 0·025 inch (0·6 millimetre) in diameter. Further experiments, made with a view to ascertaining the most favourable conditions for connecting the igniters to the cable by clamp-connections, instead of direct, led to the conclusions: that it is best to connect each igniter to the cable by means of a clamp, or in pairs where the number is large, but that to connect three or more igniters with one branch leading to the cable is inadvisable, owing to the increased resistance thus produced. C. S.

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## RECENT SINKINGS IN THE RUHR DISTRICT.

*Neuere Schachtbohrungen im Ruhrbezirk.* *By* L. HOFFMANN. *Glückauf*, 1901, *vol. xxxvii., pages* 369-373, *and* 1 *plate.*

*Adolf von Hansemann Colliery.*—The sinking of No. III. shaft through quicksand down to 24½ feet (7·5 metres), Grey Marl from that depth to 727 feet (221·5 metres), Upper Greensand to 738 feet (225 metres), White Marl to 826¾ feet (251·75 metres), and Lower Greensand to 833 feet (254·75 metres), with a clear diameter of 17 feet (5·2 metres), was begun, on August 8th, 1894, by a sinking-tower. Boring with the small trepan to a diameter of 9 feet 6 inches (2·9 metres) was started on August 10th, 1896, and finished at the depth of 832½ feet (254·53 metres) on December 5th; and the widening out to the diameter of 16½ feet (5·05 metres) was effected between December 20th, 1896, and October 5th, 1897. The mean monthly advance with the small trepan was 48½ feet (14·83 metres) and the maximum 59¾ feet (18·22 metres), while the respective figures for the widening out were 16¾ feet (5·1 metres) and

25½ feet (7·86 metres). Altogether 21½ months were spent in boring, giving a mean monthly advance of 8¾ feet (2·72 metres), which is the greatest speed hitherto attained in the Ruhr District, except in the case of the Dahlbusch shafts.

*Scharnhorst Colliery* (No. I. shaft), passing through similar strata, was sunk in 1873 with a clear diameter of 16 feet 4 inches (5 metres) to the depth of 384 feet (117 metres), and afterwards abandoned at the demand of the Mines Authority, because at about 230 feet (70 metres) so much water was encountered as eventually to attain 6,600 gallons (30 cubic metres) per minute; and the pumping of this quantity caused all the streams to run dry for several miles round. On the colliery coming into possession of the Harpen Company, it was decided to continue the sinking by the Kind-Chaudron method; but great difficulty was encountered in removing the four pumps below the water-level, the work being effected by divers under a pressure of 53 pounds per square inch (3·6 atmospheres). A further difficulty was the breaking of the shoes cast on the inside of the tubbing-rings for carrying the buntons; and this was effected, under water, from the surface, by means of a kind of battering ram, weighing 3 cwts. (150 kilogrammes), slung from a rope and moved up and down, while being guided by a frame that could be let down to the place required. The mean monthly advance of the boring was only 5½ feet (1·66 metres), this poor result being accounted for partly by difficulties with water, and partly by the slight height of the portion of shaft bored.

*Preussen Colliery.*—The No. I. shaft passed through quicksand down to 23 feet (7 metres), Grey Marl from that depth to 960 feet (292·64 metres), Upper Greensand to 969 feet (295·34 metres), White Marl to 1,128 feet (343·9 metres), Lower Greensand to 1,171 feet (356·1 metres) and Bunter Sandstone from that depth to 1,213 feet (369·74 metres), and was for the most part 17 feet (5·2 metres) in diameter; but, on account of the shaft not being truly round, it was not possible to give the tubbing an inside diameter of more than 13½ feet (4·1 metres). Boring was begun on August 2nd, 1897, with the small trepan, to a diameter of 8½ feet (2·6 metres) while the large trepan, weighing more than 22·3 tons, had a diameter of 15¾ feet (4·83 metres); and, to prevent a stoppage of the boring through breakage of the large trepan, the boring of the advance shaft and that to the full diameter followed one another in lengths of about 98½ feet (30 metres). The boring was finished on August 18th, 1900, having occupied almost exactly three years; and the total depth, 1,223¾ feet (373 metres), is the greatest that has hitherto been attained by a bored shaft. the mean monthly advance of 12½ feet (3·85 metres) being comparatively high considering the great depth.

As the moss stuffing-box for the Kind-Chaudron method weighed, with its accessories, about 80 tons, there could be no question of erecting it on the surface and lowering it by rods to the water-level; and accordingly the separate parts were let down by a winch and put together underground, for which purpose a platform was put up about 311¾ feet (96 metres) above the water-level, while an annular space was excavated round it. The tubbing 498¾ feet (152 metres) high, weighed altogether 1,560½ tons, a weight which has never been exceeded in any other bored shaft in the Ruhr district. With a thickness of 3¾ inches (95 millimetres), the greatest weight of a tubbing ring was 41·2 tons, the false bottom weighing 19 tons; and for this great depth the weight must have been still greater if the bottom had not been, for the first time in this case, cast of steel instead of iron.

*Preussen Colliery.*—The sinking of No. II. shaft was begun in May, 1897, 196½ feet (60 metres) distant from No. I. shaft, to a clear diameter of 17 feet

(5·25 metres), first by a sinking-tower of 22 feet (6·7 metres) inside diameter; and this method was only abandoned when the stratum was neared owing to which No. I. shaft had been drowned. After a depth of 853 feet (260 metres) had been attained, blasting brought about a water inburst of about 5,940 gallons (27 cubic metres) per minute, so that in a few hours the shaft was filled with water up to 262½ feet (80 metres) below the surface.

As all the objects used in sinking had been attached to ropes, the shaft was soon cleared ready for boring; and the headgear had been originally designed in such a manner that it could be employed for the Kind-Chaudron method. Boring was begun on May 24th, 1898, and concluded on January 25th, 1901, giving a mean monthly advance of 11 feet 5 inches (3·5 metres). The tubbing, of 14 feet 1 inch (4·4 metres) inside diameter, and 387¾ feet (118·16 metres) high, weighed altogether 1,370 tons; and each ring, varying in thickness from 3 inches (75 millimetres) to 4¼ inches (105 millimetres) weighed from 12·65 to 16·5 tons, while the false-bottom, of cast-steel, weighed 22 tons. The last-named thickness of the rings comes very near the maximum limit for cast-iron, because with any considerable increase the contraction on cooling would set up too great a strain. J. W. P.

## TAKING UP THE BORINGS OF BORED SHAFTS.

*Einrichtung zur Entfernung des Bohrschmandes aus Bohrschächten.* ANON. *Glückauf*, 1901, *vol. xxxvii., page* 280, *with vertical and horizontal sections.*

Suspended from the winding rope in a bored shaft is a cylindrical sheet-iron chamber, sliding by means of four shoes on guides at the ends of two diameters crossing one another at right angles; and for facilitating its rise and descent the top and bottom of the cylinder are connected tightly with open tubes, while a floor at about one-third of the height carries an electro-motor and a rotary pump, whose suction-pipe passes through the hollow shaft of the boring-tool, which is made to revolve by spur-and-mitre gear driven by the electro-motor. If the borings should be too coarse to pass through the pump, the latter can be disconnected for their removal by other means, and if it be preferred to drive the boring-tool by rods, the latter pass through a stuffing-box in the centre of the cylindrical chamber, although the electro-motor still drives the rotary pump, the borings passing up the delivery pipe of the latter. J. W. P.

## REPAIRING TIMBER-TUBBING WITH CEMENT.

*Charbonnage d'Abhooz et Bonne Foi-Hareng, Siège d'Abhooz: Imperméabilisation d'un Cuvelage en Bois par Injection de Ciment. By* E. FINEUSE. *Annales des Mines de Belgique*, 1901, *vol. vi., pages* 179-181.

No. 2 air-shaft was deepened from 242¾ feet (74 metres) to 689 feet (210 metres), 187½ feet (57·2 metres) having been driven upwards; but the old portion was in a very bad state, the timber-tubbing, 55¾ feet (17 metres) long, at the top of the Coal-measures allowing large quantities of water—sometimes 77,034 gallons (350 cubic metres) daily—to escape, while a masonry crib at its base diminished the sectional area of the shaft to so great an extent that it required removal. Thirty years ago, this timber-tubbing had been lined for a height of 19¾ feet (6 metres), where it passes through the gravel, with an inner tubbing of cast-iron. In 1895, the same method was adopted for the winding-shaft at a cost of £6,000 (150,000 francs). It was estimated that

a similar lining of the timber-tubbing of the air-shaft would cost about £2,000 (50,000 francs); and this work would probably have been undertaken had not the manager received information of the Portier method for repairing shafts, which was applied at a cost of only £212 (5,300 francs).

The method consists in injecting very fine and slow-setting cement behind the tubbing, the cement filling the space between it and the rock as well as the fissures in the rock. The cement is prepared on the surface; and the mixture, as thick as practicable, is led by pipes, 1·18 inches (3 centimetres) in diameter, to the place in the tubbing that has to be repaired, and where holes have been bored and cocks placed. The liquid cement is injected behind the tubbing at a pressure of 21½ pounds per square inch (1½ atmospheres), which is quite sufficient; and it was sometimes found necessary to prevent this pressure from being maintained too long, through fear that the tubbing might be burst. A hand-pump, connected with the pipes leading the cement, is used for flushing them with water after each cessation of work, and for removing any obstruction.

About 10 feet (3 metres) above the lower crib of the tubbing, 15 tons of cement were injected; and 5 hours afterwards the quantity of water was reduced to 2,200 gallons (10 cubic metres) daily. On the morrow, after 1 ton of cement had been injected immediately below the upper crib, the water-flow became slower, and injection was stopped so as not to bring too great pressure under the crib, although care had been taken to bore a few holes in it for the escape of water. Lastly, on the following day, 2½ tons of cement were injected under the crib of the cast-iron tubbing, after which the daily leakage was reduced to 330 gallons (1½ cubic metres). J. W. P.

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## SUITABILITY OF VARIOUS KINDS OF WOOD FOR PIT-PROPS.

*Untersuchungen über die Gebrauchsfähigkeit verschiedener Holzarten zu Grubenstempeln.* *By* — DÜTTING *and* — QUAST. *Zeitschrift für das Berg-Hütten- und Salinen-Wesen im Preussischen Staate*, 1900, *vol. xlviii., pages* 181-206, *and* 2 *plates.*

These investigations were conducted by representatives of the Government departments of mining and forestry, with the object of determining the absolute relative values of different kinds of wood and the influence of drying upon their durability and crushing strength especially. In order to avoid abnormal results, thoroughly sound props, without defective spots, as uniform as possible in diameter, were selected. Five pieces of each kind of prop were examined, the total number tested being: 475 beech props, 335 each of oak, fir and pine props, 110 each of birch, acacia and larch props, and 30 hornbeam props; or altogether 1,840 props.

The props were felled in February, 1898, carefully selected, measured without bark, numbered and piled up crosswise in order to dry as thoroughly as possible. In order to determine the influence of different modes of stacking upon drying, a limited number of 4 pieces each of fir and beech props were piled as above crosswise under cover. A second similar lot was placed slopingly point upwards, and a third similar lot point downwards. For eight weeks, these props were weighed weekly, the results being as follows:—

| Method of Storage. | Loss of Weight during 8 Weeks. Beech Props. Per cent. | Fir Props. Per cent. |
|---|---|---|
| Piled crosswise ... ... ... ... | 18·3 | 15·2 |
| Set point downwards ... ... | 15·4 | 14·1 |
| Set point upwards ... ... ... | 14·2 | 15·5 |

## TABLE I.—RESULTS OF EXPERIMENTS ON BEECH AND OAK.

| Nature of the Wood. | BEECH. Breaking-strain per square centimetre (= 0·155 square inch). | | | | | | | | | | OAK. Breaking-strain per square centimetre (= 0·155 square inch). | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 metre long. | 3½ feet long. | 1½ metres long. | 5 feet long. | 2 metres long. | 6⅝ feet long. | 2½ metres long. | 8½ feet long. | Averages. | | 1 metre long. | 3½ feet long. | 1½ metres long. | 5 feet long. | 2 metres long. | 6⅝ feet long. | 2½ metres long. | 8½ feet long. | Averages. | |
| | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. |
| Immediately after felling—with bark .. .. | 233·0 | 514 | — | — | 165·1 | 364 | — | — | 187·6 | 414 | — | — | — | — | — | — | — | — | — | — |
| 3 months after felling—without bark .. .. | 286·9 | 632 | 249·9 | 551 | 181·2 | 400 | 196·3 | 433 | 218·6 | 4 2 | 221·7 | 489 | 153·0 | 337 | 170·0 | 375 | 142·7 | 315 | 164·5 | 363 |
| 5 do. do. seasoned, with bark .. | 295·8 | 652 | 253·7 | 559 | 229·1 | 505 | 207·5 | 458 | 237·8 | 524 | 200·0 | 441 | 160·8 | 354 | 127·5 | 281 | 151·5 | 334 | 154·3 | 340 |
| Do. do. do. without bark .. | 304·2 | 671 | 198·3 | 437 | 171·7 | 379 | 169·6 | 374 | 201·6 | 444 | 214·6 | 473 | 148·5 | 328 | 150·9 | 333 | 183·6 | 405 | 171·0 | 377 |
| Do. do. do. blazed .. .. | 316·3 | 697 | 283·8 | 626 | 172·9 | 381 | 157·5 | 347 | 216·2 | 477 | — | — | — | — | — | — | — | — | — | — |
| Seasoned after 3 months storage at bank—with bark | 270·6 | 597 | 281·6 | 621 | 255·5 | 563 | 187·8 | 414 | 238·3 | 525 | 266·3 | 587 | 214·8 | 473 | 172·8 | 381 | 163·8 | 361 | 193·2 | 426 |
| Do. do. do. without bark | 282·5 | 623 | 205·6 | 453 | 189·7 | 418 | 218·7 | 482 | 217·9 | 480 | 183·2 | 404 | 209·6 | 462 | 158·0 | 348 | 172·9 | 381 | 176·2 | 389 |
| Do. do. do. blazed .. | 312·0 | 688 | 265·2 | 585 | 173·2 | 382 | 217·4 | 479 | 225·0 | 496 | — | — | — | — | — | — | — | — | — | — |
| Seasoned after 3 months storage in intake-air—with bark .. .. .. .. .. | 288·7 | 637 | 282·6 | 623 | 234·2 | 516 | 230·0 | 507 | 252·4 | 557 | 206·7 | 456 | 221·8 | 489 | 204·3 | 450 | 147·2 | 325 | 188·6 | 416 |
| Do. do. do. without bark | 256·4 | 565 | 288·9 | 637 | 214·3 | 473 | 223·2 | 492 | 242·5 | 535 | 241·8 | 533 | 225·8 | 498 | 190·2 | 419 | 102·0 | 225 | 174·0 | 384 |
| Do. do. do. blazed .. | 309·6 | 683 | 222·3 | 490 | 185·0 | 408 | 170·1 | 375 | 207·3 | 457 | — | — | — | — | — | — | — | — | — | — |
| Seasoned after 3 months storage in return-air—with bark .. .. .. .. .. | 252·2 | 556 | 252·0 | 556 | 210·1 | 463 | 177·8 | 392 | 213·1 | 470 | 225·0 | 496 | 221·0 | 487 | 215·6 | 475 | 138·7 | 306 | 192·1 | 424 |
| Do. do. do. without bark | 308·7 | 681 | 260·6 | 575 | 216·8 | 478 | 210·7 | 465 | 237·9 | 524 | 237·6 | 524 | 230·3 | 508 | 206·0 | 454 | 127·3 | 281 | 186·6 | 411 |
| Do do. do. blazed .. | 285·5 | 630 | 236·4 | 521 | 195·1 | 430 | 212·7 | 469 | 224·4 | 495 | — | — | — | — | — | — | — | — | — | — |
| Seasoned after 6 months storage at bank—with bark | 321·9 | 710 | 217·7 | 480 | 248·7 | 548 | 252 8 | 557 | 251·4 | 554 | 227·7 | 502 | 164·1 | 362 | 136·9 | 302 | 151·6 | 334 | 160·0 | 353 |
| Do. do. do. without bark | 242·4 | 535 | 228·2 | 503 | 232·7 | 513 | — | — | 233·6 | 515 | 229·7 | 506 | 181·9 | 401 | 188·2 | 415 | 123·1 | 271 | 161·8 | 357 |
| Do. do. do. blazed .. | 313·9 | 692 | 220·9 | 487 | 191·7 | 423 | 129·6 | 286 | 192·4 | 424 | — | — | — | — | — | — | — | — | — | — |
| Seasoned after 6 months storage in intake-air—with bark .. .. .. .. .. | 273·7 | 604 | 188·7 | 416 | 211·7 | 467 | 178·3 | 393 | 207·2 | 457 | 261·4 | 576 | 173·7 | 383 | 164·1 | 362 | 112·8 | 249 | 163·4 | 360 |
| Do. do. do. without bark | 255·7 | 564 | 243·4 | 537 | 204·2 | 450 | 202·2 | 446 | 223·4 | 493 | 331·4 | 731 | 179·0 | 395 | 202·0 | 445 | 151·2 | 334 | 205·3 | 453 |
| Do. do. do. blazed .. | 352·2 | 777 | 202·9 | 447 | 185·2 | 408 | 191·0 | 421 | 157·4 | 347 | — | — | — | — | — | — | — | — | — | — |
| Seasoned after 6 months storage in return-air—with bark .. .. .. .. .. | 198·5 | 438 | 147·2 | 325 | 156·2 | 344 | 132·7 | 293 | 151·9 | 335 | 265·4 | 585 | 153·3 | 338 | 143·7 | 317 | 128·3 | 283 | 162·2 | 358 |
| Do. do. do. without bark | 193·6 | 427 | 191·1 | 421 | 167·0 | 368 | 159·8 | 352 | 174·3 | 384 | 242·6 | 535 | 125·1 | 276 | 134·7 | 297 | 120·8 | 266 | 145·9 | 322 |
| Do. do. do. .. blazed .. | 172·2 | 381 | 136·6 | 301 | 121·6 | 268 | 127·8 | 282 | 137·0 | 302 | — | — | — | — | — | — | — | — | — | — |
| Whole series artificially dried without bark— | | | | | | | | | | | | | | | | | | | | |
| Immediately after drying .. .. | — | — | 260·1 | 573 | — | — | — | — | — | — | — | — | 200·9 | 443 | — | — | — | — | — | — |
| Stored at bank for 3 months after drying .. | — | — | 256·0 | 565 | — | — | — | — | — | — | — | — | 154·7 | 341 | — | — | — | — | — | — |
| Kept for 3 months after drying in intake-air | — | — | 230·4 | 508 | — | — | — | — | — | — | — | — | 190·3 | 420 | — | — | — | — | — | — |
| Kept for 3 months after drying in return-air | — | — | 227·4 | 501 | — | — | — | — | — | — | — | — | 157·6 | 347 | — | — | — | — | — | — |
| Kept for 6 months after drying at bank .. | — | — | 324·1 | 715 | — | — | — | — | — | — | — | — | 242·9 | 536 | — | — | — | — | — | — |
| Kept for 6 months after drying in intake-air | — | — | 264·9 | 584 | — | — | — | — | — | — | — | — | 240·8 | 531 | — | — | — | — | — | — |
| Kept for 6 months after drying in return-air | — | — | 217·8 | 480 | — | — | — | — | — | — | — | — | 215·5 | 475 | — | — | — | — | — | — |

## Table II.—Results of Experiments on Pine and Fir.

| Nature of the Wood. | Pine. Breaking-strain per square centimetre (= 0·155 square inch). 1 metre long. | | 3½ feet long. | | 1½ metres long. | | 5 feet long. | | 2 metres long. | | 6½ feet long. | | 2½ metres long. | | 8½ feet long. | | Averages. | | Fir. Breaking-strain per square centimetre (= 0·155 square inch). 1 metre long. | | 3½ feet long. | | 1½ metres long. | | 5 feet long. | | 2 metres long. | | 6½ feet long. | | 2½ metres long. | | 8½ feet long. | | Averages. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. |
| Immediately after felling—with bark | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | 185·1 | 408 | — | — | — | — | — | — | 140·7 | 310 | — | — | — | — | 155·7 | 343 |
| 3 months after felling—without bark | 191·7 | 423 | 214·6 | 473 | 180·4 | 398 | 171·3 | 378 | 187·5 | 414 | | | | | | | | | 237·0 | 523 | 177·0 | 390 | 167·0 | 368 | 148·0 | 326 | 173·0 | 381 | | | | | | |
| 5 do. do. seasoned, with bark | 196·5 | 433 | 222·8 | 491 | 215·3 | 476 | 178·5 | 394 | 200·4 | 442 | | | | | | | | | 267·0 | 589 | 178·0 | 392 | 171·0 | 377 | 110·0 | 243 | 161·1 | 355 | | | | | | |
| Do. do. do. without bark | 253·4 | 559 | 258·1 | 569 | 245·3 | 541 | 204·1 | 450 | 234·8 | 518 | | | | | | | | | 269·0 | 593 | 232·0 | 511 | 196·0 | 432 | 151·0 | 333 | 202·0 | 445 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Seasoned after 3 months storage at bank—with bark | 230·0 | 507 | 211·2 | 466 | 196·8 | 434 | 168·7 | 372 | 193·7 | 427 | | | | | | | | | 235·8 | 520 | 217·9 | 480 | 136·2 | 300 | 117·5 | 259 | 164·9 | 364 | | | | | | |
| Do. do. do. without bark | 239·8 | 529 | 259·7 | 573 | 266·5 | 587 | 206·4 | 455 | 238·5 | 526 | | | | | | | | | 238·9 | 527 | 234·9 | 518 | 220·3 | 486 | 160·5 | 354 | 206·5 | 455 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Seasoned after 3 months storage in intake-air—with bark | 188·1 | 415 | 225·4 | 497 | 201·5 | 444 | 149·2 | 329 | 187·1 | 413 | | | | | | | | | 202·0 | 445 | 201·8 | 445 | 219·2 | 483 | 137·0 | 302 | 183·4 | 404 | | | | | | |
| Do. do. do. without bark | 210·7 | 464 | 275·2 | 607 | 226·0 | 498 | 189·0 | 417 | 223·1 | 492 | | | | | | | | | 215·9 | 476 | 244·9 | 540 | 239·8 | 529 | 127·4 | 281 | 200·1 | 441 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Seasoned after 3 months storage in return-air—with bark | 198·2 | 437 | 185·3 | 409 | 221·3 | 488 | 189·8 | 418 | 189·1 | 417 | | | | | | | | | 214·9 | 474 | 212·5 | 468 | 211·5 | 466 | 168·3 | 371 | 193·8 | 427 | | | | | | |
| Do. do. do. without bark | 211·5 | 466 | 244·3 | 539 | 185·6 | 409 | 181·4 | 400 | 211·6 | 467 | | | | | | | | | 243·2 | 536 | 247·9 | 547 | 233·3 | 514 | 160·9 | 355 | 213·5 | 471 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Seasoned after 6 months storage at bank—with bark | 213·7 | 471 | 212·2 | 468 | 227·7 | 502 | 144·6 | 319 | 193·7 | 427 | | | | | | | | | 250·2 | 552 | 197·6 | 436 | 184·9 | 408 | 150·5 | 332 | 191·1 | 421 | | | | | | |
| Do. do. do. without bark | 218·8 | 482 | 189·6 | 418 | 219·9 | 485 | 139·0 | 306 | 182·8 | 403 | | | | | | | | | 252·1 | 556 | 229·0 | 505 | 192·3 | 424 | 145·8 | 322 | 194·1 | 428 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Seasoned after 6 months storage in intake-air—with bark | 216·5 | 477 | 162·2 | 358 | 177·9 | 392 | 175·7 | 387 | 178·9 | 394 | | | | | | | | | 254·1 | 560 | 226·9 | 500 | 156·2 | 344 | 160·7 | 354 | 188·1 | 415 | | | | | | |
| Do. do. do. without bark | 263·2 | 580 | 239·4 | 528 | 228·2 | 503 | 199·3 | 439 | 226·9 | 500 | | | | | | | | | 318·4 | 702 | 226·5 | 499 | 178·9 | 394 | 160·5 | 354 | 204·2 | 450 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Seasoned after 6 months storage in return-air—with bark | 91·9 | 203 | 111·9 | 247 | 125·4 | 277 | 170·6 | 376 | 134·5 | 296 | | | | | | | | | 148·8 | 328 | 129·6 | 286 | 166·0 | 366 | 153·5 | 338 | 156·0 | 344 | | | | | | |
| Do. do. do. without bark | 124·6 | 275 | 134·8 | 297 | 153·1 | 338 | 142·7 | 315 | 141·5 | 312 | | | | | | | | | 195·2 | 430 | 138·1 | 304 | 134·8 | 297 | 75·4 | 166 | 122·6 | 270 | | | | | | |
| Do. do. do. blazed | — | — | — | — | — | — | — | — | — | — | | | | | | | | | — | — | — | — | — | — | — | — | — | — | | | | | | |
| Whole series artificially dried without bark—Immediately after drying | — | — | 241·5 | 532 | — | — | — | — | — | — | | | | | | | | | — | — | 207·5 | 457 | — | — | — | — | — | — | | | | | | |
| Stored at bank for 3 months after drying | — | — | 241·6 | 533 | — | — | — | — | — | — | | | | | | | | | — | — | 297·4 | 656 | — | — | — | — | — | — | | | | | | |
| Kept for 3 months after drying in intake-air | — | — | 235·3 | 519 | — | — | — | — | — | — | | | | | | | | | — | — | 201·8 | 445 | — | — | — | — | — | — | | | | | | |
| Kept for 3 months after drying in return-air | — | — | 224·9 | 496 | — | — | — | — | — | — | | | | | | | | | — | — | 207·4 | 457 | — | — | — | — | — | — | | | | | | |
| Kept for 6 months after drying at bank | — | — | 271·1 | 598 | — | — | — | — | — | — | | | | | | | | | — | — | 283·3 | 625 | — | — | — | — | — | — | | | | | | |
| Kept for 6 months after drying in intake-air | — | — | 240·2 | 530 | — | — | — | — | — | — | | | | | | | | | — | — | 245·1 | 540 | — | — | — | — | — | — | | | | | | |
| Kept for 6 months after drying in return-air | — | — | 216·8 | 478 | — | — | — | — | — | — | | | | | | | | | — | — | 240·7 | 531 | — | — | — | — | — | — | | | | | | |

TABLE III.—RESULTS OF EXPERIMENTS ON LARCH, BIRCH, ACACIA, AND HORNBEAM.

| Nature of the Wood. | Breaking-strain per square centimetre (= 0·155 square inch). | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | LARCH. | | BIRCH. | | ACACIA. | | HORNBEAM. | |
| | 1 metre long. | 3½ feet long. | 1 metre long. | 3½ feet long. | 1½ metres long. | 5 feet long. | 1½ metres long. | 5 feet long. |
| | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. | Kilogms. | lbs. |
| Immediately after felling—with bark | — | — | — | — | — | — | — | — |
| 3 months after felling—without bark | 203·7 | 449 | 282·9 | 624 | 255·1 | 562 | 211·4 | 466 |
| 5 do. do., seasoned—with bark | 202·6 | 447 | 281·9 | 621 | 218·3 | 481 | 199·5 | 440 |
| Do. do. do. without bark | 235·3 | 519 | 292·7 | 645 | 255·4 | 563 | — | — |
| Do. do. do. blazed .. | — | — | — | — | — | — | — | — |
| Seasoned after 3 months storage at bank—with bark .. .. .. .. | 221·5 | 487 | 274·6 | 605 | 282·3 | 622 | — | — |
| Do. do. do. without bark | 185·6 | 409 | 271·5 | 599 | 313·2 | 690 | — | — |
| Do. do. do. blazed .. .. | — | — | — | — | — | — | — | — |
| Seasoned after 3 months storage in intake-air—with bark .. .. .. | 204·5 | 451 | 233·7 | 515 | 222·9 | 491 | — | — |
| Do. do. do. without bark | 219·9 | 485 | 235·7 | 520 | 339·3 | 748 | — | — |
| Do. do. do. blazed .. .. | — | — | — | — | — | — | — | — |
| Seasoned after 3 months storage in return-air—with bark .. .. .. | 180·7 | 398 | 224·2 | 494 | 276·2 | 609 | 225·9 | 498 |
| Do. do. do. without bark | 193·4 | 426 | 251·1 | 554 | 292·8 | 646 | 289·3 | 638 |
| Do. do. do. blazed .. .. | — | — | — | — | — | — | — | — |
| Seasoned after 6 months storage at bank—with bark .. .. .. .. .. | 233·0 | 514 | 279·4 | 616 | 213·5 | 471 | — | — |
| Do. do. do. without bark | 185·4 | 409 | 306·7 | 676 | 211·5 | 466 | — | — |
| Do. do. do. blazed .. .. | — | — | — | — | — | — | — | — |
| Seasoned after 6 months storage in intake-air—with bark .. .. | 244·9 | 540 | 277·7 | 612 | 213·6 | 471 | — | — |
| Do. do. do. without bark | 263·6 | 581 | 262·1 | 578 | 276·9 | — | — | — |
| Do. do. do. blazed .. .. | — | — | — | — | — | — | — | — |
| Seasoned after 6 months storage in return-air—with bark .. .. .. | 189·5 | 418 | 134·8 | 297 | 266·6 | 588 | 96·3 | 212 |
| Do. do. do. without bark | 155·2 | 342 | 203·7 | 449 | 264·8 | 584 | 119·8 | 264 |
| Do. do. do. blazed .. .. | — | — | — | — | — | — | — | — |
| Whole series artificially dried without bark— | | | | | | | | |
| Immediately after drying .. | 237·5 | 524 | 295·1 | 651 | 230·5 | 508 | — | — |
| Stored at bank for 3 months after drying .. .. .. .. .. | 296·5 | 654 | 321·9 | 710 | 295·1 | 651 | — | — |
| Kept for 3 months after drying in intake-air .. .. .. .. | 205·8 | 454 | 278·8 | 615 | 199·8 | 440 | — | — |
| Kept for 3 months after drying in return-air .. .. .. | 216·5 | 477 | 241·8 | 533 | 246·2 | 543 | | — |
| Kept for 6 months after drying at bank .. .. .. .. | 278·4 | 614 | 380·6 | 839 | 343·9 | 738 | | — |
| Kept for 6 months after drying in intake-air .. .. .. .. | 265·3 | 585 | 309·7 | 683 | 337·5 | 744 | — | — |
| Kept for 6 months after drying in return-air .. .. .. .. .. | 243·4 | 537 | 245·5 | 541 | 364·5 | 804 | — | — |

In the experiments, the props were submitted to hydraulic pressure in an iron frame until breaking occurred. Fracture in the majority of the props commenced by bending; more rarely, and rather in the case of green than in that of seasoned wood, by the splitting of the wood-fibres. Fracture was therefore almost invariably caused by buckling. It did not, however, seem possible to calculate the results of these experiments by means of the formulæ usually employed for buckling. These formulæ depend upon the theory of elasticity, and therefore are only true within elastic limits, and not up to fracture. Furthermore, these formulæ are only applicable to columns, whose length is more than fifteen times the diameter, a case that never or only exceptionally occurred in the props used for these experiments. Although it was not possible, however desirable it might have been, to employ props of absolutely equal diameter, the only resource left was to

determine the resistance to crushing of the material per square centimetre (0·155 square inch), and thus to compare the different kinds of wood. The results recorded in Tables I., II. and III. show, almost throughout, a certain degree of crushing strength that decreases with the length, which is not surprising, having regard to the unequal structure of wood, but cannot be expressed by a definite mathematical formula; therefore for the different lengths the average strength has been calculated without any regard to such weakening effect of length.

Tables I., II. and III. summarize the most important results contained in the several tables attached to the paper.

The following conclusions may be drawn:—

(1) On account of the great divergencies in the results, definite numerical conclusions cannot be given. It may nevertheless be asserted that under favourable circumstances beech is one of the most resistant of woods, whilst the crushing-strength of oak has been over-estimated by miners.

(2) Thorough drying, which is favoured by blazing and barking at the proper time, and which diminishes the cost of freights by lessening the weight, also increases the density, capacity for warning before breaking, durability and inclination to splintery fracture.

(3) The toughness as indicated by the slowly returning pressure-gauge is less in the case of conifers than in other woods.

(4) Woods that have a true heart-wood, especially oak and acacia, resist the decomposing influences of the return-air longest. Coniferous woods, such as pine and larch, resist the effects of the return-air longer than hornbeam, beech and birch, which are destroyed most rapidly. Conifers cannot, however, be looked upon as woods suitable for lasting a long time in roadway timbering. Older coniferous wood would be more durable.

(5) The influence of the return-air is indicated perhaps firstly in the tendency to short fracture; next in decrease of strength, toughness and capacity for warning before fracture. Thick props are more affected than thin ones.

(6) The extent to which the capacity for giving warning before fracture is affected by moisture cannot be definitely determined.

(7) With sound woods sufficiently dried, the fracture is always splintery. Normally it occurs in the middle; in other cases it occurs in defective spots; and in the case of coniferous woods, chiefly at the resinous knots of the branches. In other woods, the fracture is determined less by branches and wind-shake than by bends.

(8) The specific weight, depending as it does upon moisture, naturally varies within very wide limits. Birch and beech appear to be the heaviest; after this, oak, acacia, hornbeam, fir, larch and pine. H. L.

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## PROTECTION OF THE SURFACE FROM SUBSIDENCE.

*Der Schutz der Oberfläche gegen Gefährdung durch den Bergbau, nach der neuesten Spruchpraxis.* *By* TH. ANDRÉE. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 525-531.

In 1886, it was enacted in Austria that mine-owners were bound to take all necessary precautions to avert any damage to the property of others. This was opposed to the view till then held of the relation between the mine-owner and the ground-landlord, according to which the former was only compelled to take such steps to protect the surface as were required to avoid

danger to life and property, and were compatible with the objects of working the mine. In consequence of this regulation, it was decided in 1897 that the ground-landlord might compel the mine-owner to take such measures of safety as would secure his property against every kind of damage, thus practically allowing him to put a stop to mining, as soon as it came under his ground. New regulations therefore provided that it was only necessary to protect the surface in such a way that it could still be used for the same purpose as before, and that the mine-owner was not obliged to acquire permanent possession of the ground. Compulsory expropriation was also permitted.

During the interval elapsing between the two regulations, there were constant appeals and complaints. These were not wholly set aside by the later regulations, because they did not clearly assert that the mines were independent of the surface. A vital point was whether it was necessary so to protect the surface that the ground could be used in the same way as heretofore, or whether the mine-owner was obliged to make it safe if used for another purpose, such as building. In 1898, however, the highest Austrian court upheld a decision compelling the mine-owner to take such precautions that if, in course of time, the ground were required for building, there should be no difficulty.

It is this decision which the writer controverts. Land is rather easily authorized for building in Austria, and is sometimes allotted without the mine-owner being able to intervene. Thus, the mine might conceivably be at the mercy of the ground-landlord, and that although his property had never previously been worth building on. He might even demand this protection if the ground were not ultimately used for building. If such were the rule, most coal-mines in Austria would have to stop work. In mining laws, a sharp distinction is drawn between damage to another's property and endangering and jeopardizing that property, but the courts apparently consider the least damage done to the surface as constituting a danger to its safety. The writer maintains that the two are not the same, and he cites a case where, a question arising 40 years ago of extending the mines under a town in Moravia, the houses were examined, and the walls of several found to be already cracked. These fissures, although exactly like those caused by mines, were the result of defective foundations and bad building-material. Nevertheless most of these houses are still standing, thus proving that a house may be actually damaged and yet safe. The original object of mining regulations was doubtless not unduly to fetter that industry, but to enable or even compel the mine-owner to extract the produce of the mine, and with certain minerals this cannot be done without affecting the surface. In the Ostrau district, however, all kinds of buildings, railway-stations, waterworks, etc., are erected over mines with perfect safety.

Where ground after being properly supported can only be used as arable land, and thus the rent from it is lowered, the mere diminution in the value of the land can, according to present regulations, enable the ground-landlord to stop the mine. The right of expropriation would not avail, because few mine-owners are rich enough to buy up all the land above their mine. At present, the mine-owner is compelled at considerable loss, to leave pillars of valuable coal standing to support the mine. If the ground is really unfit for use, expropriation is doubtless the only remedy, but the process is too slow for the rapid development of a mine in Austria, and should be expedited.

B. D.

## TRANSIT-ARRANGEMENTS AT AN AMERICAN COKE-PLANT.

*The New Coke-plant of the Eureka Fuel Company in the Klondike Region, Pennsylvania: A Complete Modern Plant.* By J. P. BRENNEN. *Mines and Minerals (Scranton, Pennsylvania)*, 1901, *vol. xxi., pages* 385-388, *with a map and* 7 *illustrations in the text.*

The coal-field operated by the Eureka Fuel Company comprises some 6,500 acres. On the eastern limits, ideal conditions occur for the development of drift-mines, whilst on the west, shafts are required. The Leckrone and Footedale plants, each comprising 400 coke-ovens, are in operation; a third plant is under construction at Buffington embracing a similar number of ovens, and a fourth 400 coke-ovens plant is projected in the valley of Cat's Run, near Masontown. In their essential features, the plants are, or will be, similar, and the Leckrone plant may be taken as a typical instance of the elaborate arrangements made for easy and efficient transit at the mines.

At Leckrone, the No. 1 drift has 525 acres of coal tributary to it, all of which is self-draining. The grades on haulage-roads are in favour of the load, the main haulage being driven on the butt at an inclination of about 1 in 28. The main headings are lighted with incandescent lamps, and electric locomotives will be used. The main haulage-roads are laid with 55 pounds, and the butt-headings with 25 pounds steel rails.

The mine-cars run from the drift, by gravity, 550 feet to the foot of an incline, whence they are hauled to the tipple by an electrically driven sprocket-chain, dogs on the chain engaging in brackets on the car-bottoms. The incline rises 1 in 4, is 250 feet long, and the dogs are spaced so that 11 wagons can be placed on the chain at once. The cars are emptied into the bin by two Phillips dumps, the empty cars being automatically returned to the top of the incline, and there caught by a similar sprocket-chain descending the incline. From the foot of the incline, the cars run by gravity by a kip-track to the drift-mouth.

The coal-bin has a capacity of 1,000 tons; it is 60 feet high from the foundation to the dumping-floor, and 17½ feet from the foundations to the rail of the lurry track under the bin. It is a steel structure throughout. Provision is made for the loading of screened coal into cars, and independent sidings are laid. From this steel-bin to the coke-ovens, a steel trestle, 200 feet long, carries the track for the lurries. Each lurry is provided with an electric motor, the trolley-wire on the coke-ovens being carried on gas-pipe poles attached at the bottom to an extension from the cast-iron ties under the rails. The coke-ovens are built on a grade of 1 in 100 in favour of the loaded lurry and loaded coke-car. The coke-yards are 33 feet wide, the yard-walls being 10 feet above the loading track.

Electricity is, almost exclusively, the form of power used at these plants, and steam is supplied by tubular boilers, 6 feet in diameter by 20 feet long.

X. Y. Z.

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## BALANCE-LIFT FOR CAGING OPERATIONS.

*Note sur une Balance Briart installée au Puits No.* 6 *des Charbonnages de la Russie méridionale, à Gorlowka.* By A. LEBRUN. *Revue Universelle des Mines, etc.*, 1901, *vol. liv., pages* 98-105, *and* 1 *plate.*

Gorlowka colliery, 958 feet (292 metres) deep, in the south of Russia, is served by a 700 horsepower winding-engine; and the four-decked cages have two tubs on each deck, each tub holding ½ ton of coal. When the tubs were

changed by hand, underground and on the surface, the maximum output was 140 tubs per hour; but since the balance-lift has been introduced 200 tubs are wound regularly, while 306 tubs per hour have been wound for 5 consecutive hours. With a steam-pressure on the piston of 44 pounds per square inch, the engine is capable of raising 4 tons, so that 8 tubs (each containing ½ ton of coal) can be taken up at a lift; but, with this pressure, the engine cannot lift 8 full tubs, if 2 of them contain stone.

The lift, occupying the sump which has been enlarged for the purpose, is suspended from two chains passing over sheaves and double-grooved pulleys (keyed upon a brake-shaft), their other ends being connected with the guide-rods of the counter-weights, so that the whole system is suspended from this shaft. The lift-platform is made of four oaken timbers, 8 inches (20 centimetres) square, jointed and bolted together; and for deadening shocks, while compensating the play caused by a stretching of the cage-chains, the timbers have been covered with old ropes. The maximum load carried by one of the lift-chains is equal to three-fourths of the dead weight, plus the useful load, that is, 6¾ tons. The circumference of the double-grooved pulleys is equal to their maximum travel, so as to prevent a link from riding over another when the chain is wound up. The brake-blocks are brought together against the sheave by a right-and-left-handed screw worked by a hand-wheel.

When the balance-lift is at rest, the counter-balance weights are upon their seats, and the upper platform is at the onsetting level, so that the lower deck of the cage, on being set down, comes exactly to the level of the landing, and the first counter-balance weight should balance the total dead-weight of ½ ton. When two full tubs are substituted for empty tubs, the excess of weight given by the total load permits, on the brake being eased, the descent of the platform and consequently the rising of the first counter-balance weight until the latter butts against the second. As the distance from one counter-balance weight to another is equal to that between the decks of the cage, the second deck then comes to the caging-level, and the same thing occurs for the third caging operation; but for the fourth, the cage stops when the platform reaches the bottom of its travel. The stretching of the chains and irregularity of the loads require the regulating action of the brake, which lowers and stops the balance-platform with great precision. The caging operations at the bottom of the shaft are effected with ease and rapidity, being generally finished before those at bank, which last from 28 to 32 seconds. J. W. P.

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## CLOSING THE ENDS OF WINDING-CAGES.

*Charbonnages d'Oignies-Aiseau: Fermeture des Cages.* *By* C. MINSIER. *Annales des Mines de Belgique*, 1901, *vol. vi., pages* 170-172, *with a drawing in the text.*

The closing arrangement consists of a system of bars forming equal rhomboidal figures, articulated at their summits, and another series of bars arranged transversely, resting on the summits of the rhomboidal figures for preserving their shape.

The guard, which is worked from the inside as well as the outside of the cage, is attached to the cage, and when not in use is protected from injury, while it is light and simple. J. W. P.

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## FLAT MANILLA ROPES FOR WINDING FROM GREAT DEPTHS.

*Étude théorique et pratique sur l'Emploi des Cables plats en Aloès (Abaca) comme Engins d'Extraction a grande Profondeur.* By CHARLES VERTONGEN. *Revue Universelle des Mines, etc.*, 1901, *vol. liv., pages* 1-98, 151-205, *and* 264-291; *with a figure in text and* 3 *plates.*

The object of this essay is (1) to modify the section formerly proposed by the author and consequently the formulæ for fixing the dimensions, longitudinal section and weight of the ropes; (2) to apply these new formulæ to the calculation of the radii of winding upon the pulley, the number of revolutions made by the winding-pulleys, the angular and winding speeds, the moments of resistance during a lift with one and with two cages, and the dimensions of the winding-engine cylinders; (3) to render the application of these formulæ very simple and practical by adding tables easy of reference; (4) to show by diagrams the law governing the different variable values according to the depth and the rope-tensions adopted; (5) to establish, with a view to winding from great depths, the relation existing between the number of strands in the rope and the total load to be raised, so as to avoid too great strain when the rope is bent round the pulley, and thus ensure a normal life to the ropes; (6) to seek, for the various tensions adopted, the maximum depth for which it is possible, at the same time, to satisfy the condition of equal effective moments of resistance at the beginning and at the end of a lift, and also that of being able to stow a sufficient reserve of rope at the centre of the winding-pulley, while subsidiarily showing that, as regards ropes of equal resistance, those calculated in accordance with the author's formulæ increase this limit from 23 to 26 per cent.; (7) to show by diagrams the proportional variation of the effective resistance during the lift with respect to the moment of the mean effort, for various depths and rope-tensions, when winding with one and also with two cages; (8) to show that these diagrams are constant when the depth, the extreme tensions and the ratio of the dead-weight to the total load are constant; and these diagrams are independent of the total load to be raised and the number of strands composing the rope; (9) to show by actual applications that the ratio of the dead-weight to the total load varying within the usual limits is from 0·5 to 0·6, with given depth and extreme tensions; (10) to settle the exact formulæ of the mechanical work to be exerted for raising the total load, or a fraction thereof with only one rope and without the balancing effect of the other rope; (11) to also settle the exact formulæ giving the moment of the maximum effort produced by raising the total load, or a fraction thereof with one rope without the balancing effect of the other; and (12) to show by a complete application the manner of proceeding in order to determine all the conditions of the problem without resorting to the tables given by the author.

The author's observations lead him to give the following figures for the proportional tensions to be adopted for different depths:—

| | DEPTHS. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Less than | From | to | From | to | From | to | Above |
| Feet ... | 1,300 | 1,300 | 2,000 | 2,000 | 2,600 | 2,600 | 3,200 | 3,200 |
| Metres .. | 400 | 400 | 600 | 600 | 800 | 800 | 1,000 | 1,000 |
| TENSION IN POUNDS PER SQUARE INCH (MEAN). | | | | | | | | |
| Pounds ... | 960 | | 1,100 | | 1,210 | | 1,365 | 1,450 |
| TENSION IN KILOGRAMMES PER SQUARE CENTIMETRE (MEAN). | | | | | | | | |
| Kilogrammes | 60-75 | | 75-80 | | 80-90 | | 90-102 | 102 |

J. W. P.

## SHAFT-BARRIERS AT THE SAINT-ETIENNE COLLIERIES.

*Note sur différents Types de Barrières automatiques employées à la Division du Treuil des Houillères de Saint-Etienne.* *By* C. FAURE. *Comptes-rendus Mensuels des Réunions de la Société de l'Industrie Minérale*, 1901, *pages* 47-49, *and* 3 *plates.*

*Extensible Barriers.*—These barriers consist of a series of open-jointed diamond-frames like lazy tongs, so that a vertical motion of 2·6 inches (65 millimetres) gives a horizontal displacement of 47 inches (1·2 metres). The barrier is closed by means of a counter-weighted lever, which is raised by the descent of the cage, and the barrier is simultaneously opened.

This barrier has the advantage of being automatic; but it also has the disadvantage of not opposing a sufficient obstacle to runaway tubs, which readily put it out of shape.

*Guillotine-barrier.*—The guillotine-barrier weighs about 176 pounds (80 kilogrammes) and is attached by a chain passing over a pulley to a balance-weight of 264 pounds (120 kilogrammes), while another chain, also passing over a pulley, connects this last-named balance-weight with another (guided by a special rail) having the same weight as the barrier. While the cages are not at the landing, the difference of weight is in favour of the barrier and the guided balance-weight, so that the heavier of the two balance-weights is lifted, the landing being then closed; but when the cage arrives at the bottom it receives the smaller guided counterweight on its roof, and the weight of 264 pounds then raises the barrier. In both cases, the available difference of weight is 88 pounds (40 kilogrammes); and the upward travel is limited by the lower barrier butting against the floor of the upper landing.

*Intermediate Landings.*—The barrier rolls on an inclined rail; and, perpendicular to the barrier, a rod comes between two small iron brackets attached to the plate in the middle and drilled with holes, into which the hook of the chain for fastening the tubs in the cage is passed, and holds the barrier in this position so long as the cage is at the landing. J. W. P.

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## HAULING-GEAR FOR MINES.

*Neue Fördereinrichtungen.* *By* IG. GÖSSEL. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 277-279, *and* 6 *figures.*

(1) *Safety-catch.*—The writer has invented an apparatus which is used on the rope-driven narrow-gauge railway at the Victoria shaft near Dux, Bohemia, where the gradient is 1 in 9, and from 1,000 to 1,100 trucks pass over it in one working day. The apparatus consists of two parts:—The releasing-gear and the safety-apparatus. The former consists of a wooden frame below the sleepers, carrying a revolving shaft, a lever and a balance-weight. The lever projects above the rails, and each truck, as it passes, strikes against it, and sets the weight swinging. If the truck is going at ordinary speed, the weight swings to and fro and comes to rest. But if the truck strikes the lever violently, as when it has slipped, and is going too fast, the lever rotates completely on its axis, and strikes up the signalling-lever. The latter carries two arms, the shorter of which establishes connection with the electric wires, and rings a bell in the engine-room.

The longer arm of the same lever works the safety-apparatus for stopping the truck. This consists of a block of wood placed below the sleepers, having

a notch into which a double-armed lever, rotating on a central axis, fits like a latch. If the truck runs down too rapidly, the balance-weight strikes against this block of wood, and causes the lever to catch into the truck-wheel. The truck presses down the lever as it passes up the rails, it is only when going down that it catches in it, and as the latch is held in position by wooden blocks, it cannot get loose. The alarm being given by the electric bell, the truck is released by pulling it upwards by hand, by means of the chain or rope, when the catch falls down of itself. Drawings of the arrangement are attached to the paper.

(2) *Automatic Switch.*—To shunt a tub from one set of rails on to one of two other lines is often necessary; and if the points are shifted by hand, it causes delay and inconvenience. To meet this difficulty, the writer has devised a method for automatically shunting tubs, right and left alternately, on to the two different sets of rails, the tubs themselves shifting the points as they pass.

The two external rails, slightly inclined outward, run upon an iron bed-plate. The points are formed by levers having two arms of unequal length, revolving on centres, and connected by iron bars and movable joints. The distances between the points are so arranged that when the one is resting against the one rail the other is open, so that if the left point is touching the outer rail, the right point is free of the corresponding rail. Thus, a tub coming along is guided into the left rail, the first set of wheels find the left point open, and continue along the outer rail, while the right wheels find the corresponding point closed. As the wheels come into contact with the revolving levers, shifting the points, the right wheel changes the direction, and the left wheel follows. The right point is open and the left closed, in readiness for the next truck passing over, which reverses the action. The distances between the points and the revolving levers must be carefully adjusted to suit the wheels of the tubs. Two tubs cannot be run immediately behind each other, but a sufficient distance, at least the length of a tub must be allowed between them. There is also a short curved continuation of the points, by means of which tubs going in different directions, can pass without difficulty. The apparatus, which is illustrated by drawings, has been working satisfactorily for some months at the Victoria mine. B. D.

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## LAMP-TESTING APPARATUS AT THE JOHANN SHAFT, KARWIN.

*Lampenuntersuchungs-Apparat am Johannschachte in Karwin.* By L. Volf. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1901, *vol. xlix., pages* 4-10, *and* 1 *plate.*

The apparatus is a modification of that designed by Dr. Schöndorf, and has the shape of an irregular V, one limb being perpendicular, so that the effect of vertical, as well as inclined, currents on the safety-lamp can be investigated.

A gas-reservoir was formed in part of a gallery by means of a triple-wall dam, about 3 feet (1 metre) thick. The gas, collecting in this chamber, has an almost constant composition, namely:—Methane, 99·27 per cent.; carbon dioxide, 0·4 per cent.; oxygen, 0·2 per cent.; nitrogen, 0·13 per cent.; and carbon monoxide, *nil*. The gas is conducted from the collecting reservoir, through about 3,000 feet (1,000 metres) of 2 inches pipe, into a double cylindrical storage-tank, holding about 300 cubic feet (9 cubic metres) from which it is supplied to the testing-apparatus through a weighted-bell pressure-regulator.

The tester consists of three lengths of tube, of rectangular cross-section (10 inches by 8 inches), the central portion being detachable and capable of modification so as to form either a straight length of about 14 feet or an irregular V. The safety-lamp to be tested is placed in this central portion of the apparatus and rests on a plate, situated in front of a (4 inches by 5 inches) iron nozzle fitted with a diaphragm (0·83 inch perforations) to prevent lighting-back from the lamp to the gas-supply. A strong pane of glass, let into the wall of the tube, enables the lamp to be viewed during the test, and flap-doors are provided to allow free vent to the gases in the event of explosion. The flow of gas and air through the tester is regulated by means of a Kœrting injector placed in the front-end of the apparatus, before an air-diaphragm of ¼ inch brass-plate pierced with 20 equal apertures. The admission of gas is controlled by a pressure-gauge, and its admixture with the indrawn air is effected by passing it through 20 small perforated pipes inside the tube, the mixing being further assisted by several sets of baffle-plates. By this means, both the velocity and the gas-content of the air-current within the apparatus can be modified as desired, the volume of gas and air corresponding to different degrees of depression, as recorded by the pressure-gauges, having been calculated and tabulated.

C. S.

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## PNEUMATIC INTERLOCKING OF AIR-DOORS.

*Note sur un Enclenchement pneumatique appliqué aux deux Portes d'une Galerie d'Introduction de Remblais dans un Puits de Retour d'Air.* *By* — FAURE. *Comptes-rendus Mensuels des Réunions de la Société de l'Industrie Minérale*, 1901, *pages* 49-51, *and* 2 *plates.*

If the ventilating pressure, at the ventilating doors, be 1·60 inches (40 millimetres), and each of the doors is fitted with a bolt carried by a piston with an area of 2½ square feet (0·25 square metre); and if the sides of the piston communicate with each side of the double doors, a pressure of 22 pounds (10 kilogrammes) will be exerted on the piston. A balance-weight of 11 pounds (5 kilogrammes) should be arranged, tending to move the piston in the contrary direction. The piston will then be impelled by a pressure of 11 pounds in one direction and drawn by a force of 11 pounds in the other direction.

When both doors are in the closed position, the bolts are held back by the balance-weights, because, owing to want of tightness between each piston and its case, but at the same time perfect tightness in the pipes, there is the same pressure on both sides of the piston. If the first door be opened, so soon as the indiarubber-cushion has uncovered the end of the corresponding pipe, the piston is immediately pushed forward, its hind face being put into communication with the atmosphere and its front face remaining in communication with the mine; and if this door be closed, so soon as the indiarubber-cushion comes against the end of the pipe, equilibrium will be set up, and the counterweight will almost immediately withdraw the bolt. If the second door be opened, the same result will be obtained with equal rapidity. If an exact interlocking of the door be effected, the difficulty resulting from attempts to open both doors simultaneously may be avoided with almost absolute certainty.

The pneumatic interlocking of air-doors can be employed in curved galleries. The system is absolutely automatic; and two doors, far apart or near together, may be interlocked with facility. J. W. P.

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## ELECTRIC FIRE-DAMP INDICATOR.

*Sur un Grisoumètre électrique.* By G. LÉON. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences*, 1901, *vol. cxxxii., pages* 1408-1410.

This indicator is distinguished in the first place from that invented by Prof. E. H. Liveing, in that it does not depend on the difference of luminosity exhibited by two platinum-wires heated by an electric current, and placed one in pure air and the other in the atmosphere to be tested, but on the difference of electric resistance shown by two such wires similarly placed. These wires are heated up to about 1,800° Fahr. by the same current, and are connected with a galvanometer the needle of which moves over a hundred divisions of the scale for every 50 milliampères. The resistances are so adjusted that the needle remains at zero when the instrument is in pure air. When the atmosphere is vitiated by pit-gas, the needle moves about 2 divisions for every thousandth part of pit-gas in the air. Experiments made underground show that the deviations of the galvanometer maintain a fairly constant ratio to the variations in percentage of fire-damp, and laboratory experiments made with atmospheres containing increasing proportions of coal-gas up to 5 per cent., show that this constant ratio may be predicated of fire-damp until very near the percentage recognized as explosive.

On the other hand, the galvanometer-deviations vary rapidly with the current furnished by an electric accumulator. It is thought, however, that the current can be kept within 2½ per cent. of absolute constancy, and this would involve only an error of 10 per cent. in the estimations. Moreover, if a resistance of 0·015 ohm be introduced into the circuit, and connected with the galvanometer by means of a commutator, it will enable the observer to verify the constancy of the current and to make the slight corrections necessary in the readings. When these are being taken, a movable screen protects the platinum-wire against air-currents.

In conclusion, the author points out that this indicator may be used for measuring all combustible gases, such as hydrogen and carbon monoxide, and makes it possible to set up fire-damp-measuring observatories, wherever convenient for scientific purposes or desirable for the security of those employed underground. L. L. B.

## SEISMOLOGICAL OBSERVATORIES AND THE EVOLUTION OF FIRE-DAMP.

*Rapport relatif à la Création de Stations Sismiques pour l'Étude des Conditions de Dégagement du Grisou.* By E. LAGRANGE. *Bulletin de la Société Belge de Géologie, de Paléontologie et d'Hydrologie*, 1901, *vol. xv., pages* 159-166.

A technical committee of the Brussels Geological Society resolved to set up a seismological station in the workings of the Agrappe colliery, in combination with another aboveground, situated on a neighbouring massif which so far has not been invaded by the miner. This is occupied by the wood of Colfontaine, a fairly extensive belt of forest which separates the coal-districts of Wasmes, Le Grand Hornu, etc., from the agricultural areas on the north, and is on the line of the Great Eifel fault.

In the meanwhile, the management of the Agrappe colliery are setting up a laboratory for the study of fire-damp, and this will greatly help in studying the relationship which is believed to exist between seismic phenomena and the evolution of fire-damp.

The author points out that the ancient and more compact rocks of the

earth's crust are as a rule less violently shaken by earthquakes than the overlying more loosely compacted rocks. On the other hand, if a loose porous mass of alluvium or sand is exceptionally thick, and extends over a wide area, the propagation of a seismic wave therein is gradually checked until it dies away to nothing. Evidently that is why the great North German plain is rarely disturbed by considerable earth-shocks. He goes on to argue that the proposed seismological station in the wood of Colfontaine should be set up as far away from the great fault as possible, either north or south of it. In fact, he indicates a preference for another locality, Quenast, where a great mass of intrusive porphyry pierces the Palæozoic strata. The estimated cost of the seismological station at the Agrappe colliery itself is as follows:—Von Rebeur-Ehlert pendulum, £50; timepiece and recorder, £16; photographic paper (automatically unrolling), £12; general expenses in setting up the apparatus, etc., £12; and cost of supervision, unforeseen expenses, etc., £10. But it is pointed out that magnetic recorders are desirable as well, and it is not expected that the initial £100 will anything like suffice to carry the work to a practical conclusion.

In the discussion on the foregoing report it was practically decided to purchase a second pendulum, to be set up for purposes of comparison at the Colfontaine station; and to defray this and other supplementary expenditure the Brussels Society relies upon aid from the Provincial Council of Hainaut and from the Belgian Government, both of which bodies appear to be impressed with the importance of the proposed observations. L. L. B.

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## PUMPING AND SPRAYING ARRANGEMENTS AT THE BRUCH COLLIERY.

*Wasserwirthschaft der Gewerkschaft Brucher Kohlenwerke.* *By* A. PADOUR. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1901, *vol. xlix., pages* 77-82, *and* 1 *plate.*

*Pumping-engine.*—After being in work for several years, the 1,000 horse-power pumping-engine at the Johann, Moriz and Gutmann shafts of the Bruch colliery was found to have so far reduced the influx of water into the workings as to lead to risk of fire from the resulting dryness of the lignite coal, in addition to which the water had increased in hardness from 6 degrees to 16 or 19 degrees and become unfit for boiler-use without purification. It was therefore decided to centralize the pumping-plant at the Johann shaft, the water from the newly acquired Pluto and Paul shafts being led through a drainage-gallery into the sump, and that from the other two shafts being delivered by syphons. The new tandem compound condensing pumping-engine drives a differential Riedler pump lifting 660 gallons (3 cubic metres) of water per minute at a working speed of 80 revolutions. It is erected in an underground chamber formed by taking out a pillar of coal, 56 feet long by 23 feet wide and 20 feet high, the rock-pressure being supported by a number of pillars, 5 feet by 40 inches, made of seasoned timbers and embedded in cement. The temperature of the engine-room is kept down to 28° Cent. between the high and low-pressure cylinders, and to 38° Cent. at the receiver, by a powerful ventilating current, assisted by two Kœrting injectors, the radiation of heat from the cylinders being diminished by lagging.

The drainage-gallery, between the Pluto and Johann shafts, is closed by a strong compound dam, containing a settling-tank and provided with a

pass-bye closed by convex iron doors capable of resisting a pressure of 15 atmospheres.

Part of the pumped water is softened with lime and soda and used for boiler-feed, a 5 inches main, 5,000 feet (1,500 metres) long, delivering 130 gallons (600 litres) per minute to the Pluto shaft, 88 gallons (400 litres) per minute being led to the new works at Maria Ratschitz, through 4,000 feet (1,200 metres) of 4 and 5 inches pipe; whilst a 2¾ inches pipe, 5,700 feet (1,760 metres) long, delivers 35 gallons (160 litres) per minute to the Gutmann shaft, which also receives 65 gallons (300 litres) per minute of unpurified water for spraying.

*Spraying.*—Since 1894, a total length of 150,000 (44,920 metres) of pipe—varying in diameter between 6 inches and 1 inch—for spraying the dusty galleries, has been laid down in these workings. The pit-water used for this purpose at the Pluto, Paul and Ratschitz shafts is collected in reservoirs and distributed by compressed air or duplex steam-pumps at the Gutmann shaft, the water is stored in an iron cylinder connected with the spraying pipes; and at the Moriz shaft the spraying-water is drained from a stratum of water-bearing gravel and stored in a reservoir for use.

Branch-pipes are laid in nearly every gallery, especially those in work, and at each joint a small spraying hole (0·083 to 0·166 inch) is bored in the pipe and can be stopped by a wooden plug. In each working-place, a 1 inch pipe is fitted at the end with a gaspipe-cap containing a small (0·12 to 0·25 inch) hole; this cap can be replaced by a hose-pipe when required. The requirements of the mine in respect of spraying tax the full capacity of the water-supply, mere intermittent spraying being insufficient to prevent danger from fire. The holes 20, 25 or 30 feet (6, 8 or 10 metres) apart, deliver jets of water-spray, either against the roof, walls or diagonally across the gallery, and from 520 to 560 holes (each spraying 2 to 8 pints per minute) and 20 hose-pipes are in use every day. The spray-holes in the main headings are about 30 feet (10 metres) apart, but only about one in fifteen of these is left open during the week, although the whole are kept at work on Sundays. Except in the main headings where gulleys are provided, the water runs over the floor of the workings.

In particularly dangerous places, the spray-holes are set close together (at intervals of about 3 feet) for a distance of 65 feet (20 metres), and discharge in all directions so as to form a wet zone, the water on the sole being also banked up to a depth of ½ inch to 1 inch, in order to cool the air and prevent dust and ignition.

The tendency of this coal to oxidize results in a considerable accession of temperature in the ventilating current, the increase commencing about 1,600 feet (500 metres) from the intake-shaft in the summer (22° to 25° Cent.), and attaining the maximum (29½° to 32½° Cent.) at 6,000 feet (1,800 metres), the average increase being therefore 1° Cent. per 600 feet (170 metres); in the winter, the rise begins nearer the shaft, the initial and final temperatures being 12° and 28½° Cent., corresponding to a rise of 1° Cent. per 430 feet (130 metres). The spraying water has a temperature of 22° to 24° Cent. and cools the air 2°, but measures are being taken to introduce the water at 12° to 15° Cent. and so cool the air by 4° to 5°. C. S.

## SPRINKLING DUSTY GALLERIES AT THE ANNA AND CARL SHAFTS OF THE KÖLNER BERGWERKS-VEREIN COLLIERY AT ALTENESSEN.

*Einrichtungen zur Unschädlichmachung des Kohlenstaubes auf den Schächten Anna und Carl des Kölner Bergwerks-Vereins zu Altenessen.* *By* — WINKHAUS. *Glückauf*, 1901, *vol. xxxvii., pages* 189-194, *with* 4 *figures in the text.*

The following arrangements have been adopted for sprinkling the dust arising from several of the seams worked at the Anna and Carl shafts, Altenessen. The daily output from the former shaft is 806 tons, and from the latter 1,080 tons, of which 69 per cent. and 81 per cent. respectively are got from seams provided with sprinkling appliances.

The water used, that trickling through the walls of the shaft, is caught in gutters and conveyed to reservoirs. The Anna shaft water contains 105 parts of solid matter (gypsum with traces of salt) per 100,000, while that in the Carl shaft contains 96 parts, chiefly of salt and a small amount of gypsum. At the Carl shaft, the reservoir, which is on the 480 feet (146 metres) level, about 180 feet above the highest gallery to be sprinkled, consists of a cemented brick-tank made by damming an old cross-cut, and holds about 22,000 gallons (100 cubic metres), one day's consumption; and it is fitted at the inlet-end with a filtering layer of broken coke. In the Carl shaft, the water-tank, in the 656 feet (200 metres) level, holds 45,000 gallons (205 cubic metres), and is preceded by a clarifying overflow-tank; the daily consumption of water here is about 14,300 gallons (65 cubic metres). This tank being incapable of supplying water to the upper part of the workings, an old pump-sump, on a higher level (about 160 feet), has been converted into a reservoir, and receives the water dropping from the winding-shaft, the other being fed from the ventilating-shaft. In the Anna shaft, a single main on the third level supplies all the branches and sprinkling-nozzles.

Only three sizes of pipes, unions and valves, are employed, namely, 2 inches (51·5 millimetres) in diameter for those in the shaft, 3 inches (76·5 millimetres) in diameter in the cross-cuts and main roads, and 1 inch (25 millimetres) in diameter for pipes in the seams. The pipes are of wrought-iron, welded and galvanized inside and out, in 16 feet (5 metres) lengths, and tested to 600 pounds per square inch. The valves, of red brass, are fitted at the junctions of every sub-main and branch, so that the supply may be cut off in each section and sub-section treated. The valves supplying the hose-jets are of ½ inch bore and either fitted with threaded ends for the hose-pipe or with Feller rubber joints, which are self-tightening and answer better than the usual screw collar.

High-pressure hose is used, ½ inch (13 millimetres) in bore and ⅛ to ¼ inch (from 5 to 6 millimetres) thick. The sprinkling-nozzle, with a pressure of 150 pounds per square inch (10 atmospheres), will moisten a length of 50 feet (15 metres) from each point. Accordingly, 100 feet (30 metres) has been chosen as the distance apart of the several cocks, for thoroughly damping the roads by means of a hose 3¼ feet (1 metre) long. The larger number of cocks required by this arrangement is of slight consequence, in comparison with the great advantage of only using a short instead of a long length of hose.

No special officials are appointed to supervise the distribution-pipes, the overman of each district being held responsible. The laying and connecting of the ordinary pipes is made by the sprinkling-master (*Spritzmeister*); while unions, T pieces, etc., are connected by fitters, especially appointed to

the work. Locked chests running on wheels and containing the necessary tools, are provided in the various districts. The sprinkling of the roads, inclines and upbrows is done by the *Spritzmeister*; but that of the working-places, including the last faces of the roadways, so far as they can be reached by the furthest hose of the pipe-line, is effected by the workmen. The following rules have been drawn up for the guidance of the sprinkling-master:—

(1) Workmen appointed for damping the coal-dust must every day so thoroughly sprinkle all the roadways and airways, rises, passes and inclines in the district entrusted to their care that no dry coal-dust can be anywhere present.

(2) Especially must they take care that any coal-dust behind props or bars, behind brattices and at the faces be sufficiently damped.

(3) In working-places, not in operation, damping of the face and neighbourhood must also be effected by the sprinkling-master, while the roof, face, lying coal and neighbourhood, must be damped by the workmen in the case of working-places in operation.

(4) Defects in the pipe-line and other arrangements for sprinkling, so far as they cannot at once be made good by the sprinkling-master, must be immediately reported to the overman or his representative; and each sprinkling-master must also notify the overman or his representative when any defect or deficiency in the sprinkling arrangements prevents him from discharging his duty.

In the Anna shaft, the total length of piping amounts to 9½ miles (15,686 metres) of which 41,000 feet (12,000 metres) are 1 inch branch pipe; and 42,000 feet (12,850 metres) of gallery are sprinkled. The total cost amounted to about £1,800 for pipes and £110 for the water-tank.

In the Carl shaft, the piping covers a length of 12 miles (19,028 metres), 47,500 feet (14,570 metres) being 1 inch pipe; and the length of headings treated is 60,500 feet (18,500 metres). The cost in this case is nearly £2,200 for the pipes and £500 for the reservoirs. The working expenses per ton of coal worked from sprinkled workings amount to 1¾d. and 1½d. in the Anna and Carl shafts respectively. J. W. P. and C. S.

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## AIR-BREATHING APPARATUS: PNEUMATOPHORE.

*Outillage très simple et très sûr, d'Application aussi rapide que facile, pour rendre inoffensifs le Séjour et le Travail de l'Homme dans les Atmosphères irrespirables contaminées par des Gaz délétères.* By A. CHAUVEAU and J. TISSOT. *Comptes-rendus hebdomadaires des Séances de l'Académie des Sciences*, 1901, *vol. cxxxii., pages* 1532-1537.

The essential feature of this apparatus is an arrangement for separating the current of inspired air from that of expired air. It fulfils to the letter the following conditions, all of which the authors regard as indispensable:— (1) Adaptability to the normal and customary passages by which the currents of inspired and expired air travel, namely, to the nasal cavities and not to the buccal cavity. (2) The most complete approximation practicable, to the inlet of the air in the organism, of the system of valves which condition the separation of the two air-currents. The purpose of this is to avoid any prolongation of the channel common to both of them, whereby the quantity of vitiated air drawn into the lungs at each inspiration

would be increased. (3) Extreme mobility of the valves, which should be designed in such a way as to obviate any adhesion to the contours of the orifices which it is their function to open and close alternately. (4) Reduction of the volume and weight of the apparatus to such a point that its presence is imperceptible (as a burden) to the wearer. At the same time, it is so firmly attached as to suffer no undue displacement by reason of the movements of the wearer.

Glass nozzles are thrust into the nostrils and communicate by thin india-rubber tubing with the main apparatus. This consists of a transverse tube, so made that it can be taken to pieces for cleaning, etc., and within it are the two systems of valves: thin aluminium-discs, loosely jointed, fitting exactly on the bevelled edges of their corresponding orifices, but never sticking to them. The apparatus is fixed in front of the mouth, the chin serving as a support, and united by ligatures to a leathern skull-cap fixed on the head. In cases where it is necessary to go through poisonous atmospheres in mines, etc., the needful provision of fresh air is kept up, by attaching a flexible tube of adequate length and diameter to the apparatus: with an increase in length of tubing the diameter must be increased. Experiments have shown that in this way a man may remain without danger for 1 hour or more in an atmosphere charged with carbonic oxide, etc. The authors' experiments further tend to show that the skin, of itself, is not by any means a ready absorbent of poisonous gases. L. L. B.

## WOODEN AND MASONRY DAMS IN MINES.

(1) *Holzmauerungen in der Grube.* *By* A. HÜBNER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1901, *vol. xlix., pages* 115-117, *and* 3 *figures.*

Under the conditions prevailing in the fiery pits of northern Bohemia, where the rock-pressure is considerable and the coal is worked on the chamber system with packed headings, the provision of insulating dams for restricting outbreaks of fire, etc., is a matter of importance. The use of wood for this purpose was first introduced into the district by the author, in 1893, after other materials such as brick-ends, broken stone, ashes, etc., had proved imperfect. The wood used consists of ordinary round pit-props or old sleepers, 24 to 40 inches in length and 3 to 6 inches thick, barked, trimmed of knots, sound in the heart, and well-seasoned. The usual method of building the insulating dams is to commence at the time of laying out the working chamber, and clear out the sole of the gallery (at the site of the dam) until firm rock is reached for laying a foundation of stone- or brick-work. The walls are also bricked in contact with the solid rock, the preparatory masonry being arranged in the form of a segment leaving the open diameter from 4 to 6 inches wider than the rest of the gallery, in order to allow for the results of rock-pressure. The wooden pillars are then erected, usually 30 to 36 inches in breadth, the spaces between the round timbers being well filled with mortar, and finally the top layer is wedged up tight against the roof. Strong wooden double doors are made ready for closing the passage in case of emergency. When the worked-out chamber is left to subside, the passage-way in the dam is filled up with round timbers and well plastered to make it as far as possible gas-tight. The plaster requires renewal at intervals, when cracked by the effects of rock-pressure. When any tendency to spontaneous ignition is observed in the gallery, or fire-damp is detected, spraying should be employed; and in any case all dusty cracks

in the walls must be well stopped with plaster and the walls, roof and sole coated with mortar for about 1 foot round the dam.

For dams intended to last for a number of years, the wood must be protected from rotting by impregnation, or the dams built of masonry, in which case the wooden fittings must be preserved by coating with sodium silicate or the like. This class of compound dam has proved successful for main air-doors, airway-crossings, etc., the planks and inserted timbers, in conjunction with round timbers set against the roof, taking up a good portion of the rock-pressure and protecting the doorposts. Where the roof is likely to crumble, flat lining timbers are advisable. The construction of these wooden dams is quicker than when masonry is used, and nearly as cheap. C. S.

(2) *Verdämmungsbauten beim Přibramer Hauptwerke.* *By* FRANZ MLÁDEK. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1901, *vol. xlix., pages* 117-119, *and* 5 *figures.*

In order to save the expense of pumping out an abandoned heading, it was decided to erect a tapering wooden dam composed of 102 blocks of pine, 8½ feet long, planed and fitted true, and covered with tarred canvas, before being set up in position. Each layer was tightened by ramming in the key-wedge; and, in addition, 102 beech wedges, 30 inches long, together with a number of iron wedges, were driven in on the face next the water. The dam, however, proved leaky under the heavy water-pressure (nearly 23 atmospheres) and had to be replaced by one of rammed concrete and masonry, the latter 4 feet thick and convex, backed by 80 inches of rammed concrete and a brick arch (1½ bricks thick) also convex on the side next the concrete. Slag-bricks and cement-mortar were used, and the concrete was composed of 1 part (volume) of cement, 2 parts of granulated slag and 3 parts of gravel. The fissured character of the rock necessitated a very careful preparation of the abutment and the plastering of the walls with mortar, faced with cement, all round for 8 feet on the water side. A 3½ inches drainage-pipe and a ¾ inch air-pipe, both strengthened with iron-rings, were laid through the dam. This dam effectually keeps back the water, though the pressure has attained 24½ atmospheres. It cost about £200, as compared with a charge of nearly £400 per annum for pumping.

Other dams have been constructed in these workings, for the formation of underground reservoirs of compressed air (pressure 4 to 5 atmospheres) for working drills, pumps, etc., the dams consisting of two brick walls enclosing a core of rammed concrete. No blasting is allowed in the vicinity of these dams. C. S.

## KLEY PUMPING-ENGINE IN AN IDRIAN MINE.

*Die Kley'sche Wasserhaltungs-Dampfmaschinenanlage am Franzschachte in Idria.* *By* KARL HABERMANN. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 27-32, *and* 2 *plates.*

This mine was originally served by two pumping-engines driven by water. As these were fifty years old, and the power was not sufficient to keep the water under, a new plant was designed in 1885. A temporary pumping-engine was started in 1886, and the larger plant completed in 1895, the shaft having been enlarged and walled.

A Woolf compound beam-engine of the Kley type was selected, in which the speed could be varied from 1 to 12 revolutions per minute. It is guaranteed to lift 44 cubic feet of water 885 feet high per minute, at a speed of

6 revolutions. Both the cylinders are jacketed with boiler-steam. The diameter of the high-pressure cylinder is 31·8 inches and stroke 49 inches; the diameter of the low-pressure cylinder is 39·4 inches and stroke 6·56 feet; and the ratio of the volumes of the two cylinders is as 1 to 2·44. The length of the beam is 33 feet 8 inches and it works three pumps, the total weight of which is 65 tons. The engine is vertical-condensing double-acting; it has six valves with varying expansion and compression, and the beam is placed below the cylinders. The pumps work with pauses between the strokes, the pistons being then in the lowest positions. A small pump drains the condensation-water from the jackets, and returns it to the boilers. The centrifugal governor regulates the speed, 12½ revolutions per minute being the maximum. The beam, weighing about 18½ tons, transmits the power from the cylinders to the plunger-pumps. The cut-off varies from 25 to 53 per cent. By means of a cataract-governor combined with the valve-gear, the speed can be either continuous or intermittent. The cataract-governor, consisting of a small vertical single-acting oil-pump, acts only during the pauses. As it is made to play during the descent of the motor-pistons, there is no pause at the lower dead point. It also acts by stopping the engine automatically, in case of need.

The shaft for the pumps was sunk in 1792, and was afterwards lined with masonry throughout its whole depth of 911 feet. In one part, the thickness of the walling had to be increased to about 6 feet, to resist the pressure of the stone (slate and breccia), and the inrush of water. The bottom of the shaft was laid in concrete, and artificial reservoirs were constructed to catch the water, and to prevent the shaft from being flooded while the work was proceeding. To collect the water in the mine, and convey it to the pumping-engine underground, channels were made and faced with masonry at various levels. The shaft is now perfectly dry. It is in four divisions, two for winding, one for the workmen, and one for the water-pumps and pipes.

The water in the mine is raised to the Florian level, 55 feet below the surface, by three lifts of plunger-pumps, acting at three different levels. Two are Rittinger forcing-pumps, the third and lowest is a plunger-pump. The upper piston of the highest lift is so arranged that it raises water, both in its ascent and descent. The first set of pumps descends to the third level, a depth of 402 feet, and the head of water is 344 feet. It has two plunger-pumps, the first 12½ inches, and the second and lower about 17 inches in diameter. The second lift of the pumps descends to the ninth level, at a depth of 738 feet; it has also two plunger-pumps, and the head of water is 328 feet. The lowest lift of the pumps reaches the eleventh level, 902 feet lower. It has suction-valve chests, and the head of water is 173 feet. It carries one plunger about 18 inches in diameter. The pumps are fixed upon girders. The water is raised from the lowest to the middle level through a pipe about 16 inches in diameter. There is an overflow pipe, should more water be brought up than can be dealt with by the next lift, which delivers to the upper pumps through a somewhat smaller pipe. The forked pump-rods, weighing 65 tons, are connected to the beam by girders and cross-heads of the best steel. The weight of the pumps, and of the ascending column of water is 80 tons. Care was taken that the pumps raised water in their ascent as well as their descent, and that there was no downward thrust. The writer lays stress on the fact that the lower dead-point is in this engine passed through at diminished speed, and the pumps begin their lift at gradually increasing speed, as the pistons rise. The division of power secured by this distribution of the steam is considered of special importance. The advantages of the Kley-Woolf system as compared with the ordinary compound engine is

shown in a series of diagrams, while others, taken of the movement of the pump-rods, mark its much more gradual increase of speed.

The boilers of the elephant type comprise two upper, and four lower tubes. The total heating-surface is 1,076 square feet; boiler-pressure, 7 atmospheres; evaporation, 2½ to 3 pounds of water per square foot of boiler heating-surface; and total delivery of steam per hour, 2,640 to 3,300 pounds.

Experiments were made in 1895 and 1896 to determine the consumption of the engine. The combustible used was partly wood, partly Sagor coal; six trials were made with the former, and three with the latter. The wood was beech containing 42·65 per cent. of carbon and 14·7 per cent. of water, and having a heating value of 6,058 British thermal units per pound; it evaporated 2·9 pounds of water per pound of wood. The engine ran at 8 to 9 revolutions per minute, the mean indicated horsepower varied from 130 to 150, and the steam-pressure was 6½ atmospheres. The consumption of wood was about 8½ pounds and of steam 27·8 pounds per indicated horsepower per hour, including the jacket-steam, etc. In the second experiment made three months later, the consumption of wood was 6·3 pounds per indicated horsepower per hour, and the mean consumption of steam 23 pounds per indicated horsepower per hour. Coal was used in the third series evaporating 4½ times its weight of water; the consumption was 4·8 pounds and of steam 21·4 pounds per indicated horsepower per hour. Having been a year at work, the engine naturally ran better. The best test of economy is, however, the daily work of an engine. A table shows the consumption of this engine for two years, which works out at 30 pounds of steam per horsepower per hour; but its extremely slow speed, 4 to 8 revolutions per minute, must be taken into account. The total cost of the plant was about £11,200, and of the engine and beam alone £4,150. B. D.

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## SCREENING AND MAKING A GIVEN SAMPLE OF COAL.

*Charbonnage de Gosson-Lagasse, Siège No. 2: Triage des Charbons.* By H. HUBERT. *Annales des Mines de Belgique*, 1901, *vol. vi., pages* 175-178.

Formerly the so-called unscreened coals (*tout-venant*), both for house and industrial purposes, were constituted by the coal as brought up from the mine, tipped into wagons or boats after a summary picking: the sample being, if required, improved by addition of the larger sizes of bituminous coal separated from that destined for washing. A new plant, capable of dealing with 100 tons per hour, has been erected near the existing washery, for separating and again uniting the different sizes in the desired proportion. The chief reasons for this change are of two kinds:—On the one hand, the now almost exclusive working of thin seams with shale-bands renders efficient cleaning necessary; and on the other, the very varied composition of so-called unscreened coal renders it difficult practically to avoid delivering either an inferior sample, that gives rise to complaint, or one better than that contracted for in order to avoid complaints. In addition, the arrangements were designed to effect, by a single plant, the operations that were before performed separately at three installations, namely:—(1) A preliminary separation of the screened bituminous coal from the slack to be washed; (2) preparation and loading of the so-called unscreened coal sent off by rail; and (3) the same for that despatched by water, while at the same time every effort was made to reduce labour and breakage to a minimum.

The coal is classed by the screens into six sizes, which are remixed in the desired proportion in the loading-hopper, the slope of which only just per-

mits the coal-mixture to slide at a moderate speed; and, along all the carrying-belts except that of the dust up to ½ inch (15 millimetres) gauge, are arranged steps for the pickers, who separate the stone and the coal mixed with shale intended for firing the boilers. For the boats, the small coal of the desired composition falls, on leaving the measurer, on to inclined conveyors which raise it to the top of two large storing-bins, arranged vertically above a trench the bottom of which is on a level with the shipping-dock. In this trench run trucks, holding about 1·2 tons, and discharging at the bottom, which receive separately their slack or screened coal; and, as the boats carry at least 90 tons, the mixture becomes sufficiently re-formed. The sizes of screened coal intended for the boats are united on a horizontal conveyor, which leads it into a wide and inclined hopper descending into the above-mentioned trench. The measuring-cylinders, the working of which is checked several times in a day, permit, for deliveries by wagon, of obtaining the exact composition desired; and for the boats, the composition is determined by the number of trucks for each size, slack and screened coal. In one as in the other case, the slack remains of the desired proportion, independently of the great variations in the working that occur in the course of a day, and which are equalized by receivers and sliding-shutters, the surplus coal of any size being sent to the washing-floor. J. W. P.

## ECONOMIC CONDITIONS OF THE IRON-INDUSTRY IN LOMBARDY.

*Étude sur les Conditions économiques de l'Industrie Sidérurgique en Lombardie.* By — BABU. *Annales des Mines*, 1901, *series* 9, *vol. xix., pages* 333-337.

The ancient iron-industry of Lombardy is not merely passing through a critical phase, it is simply dying out for ever.

From east to west the principal ore-deposits are found in the Val Trompia, in the lower portion of Val Camonica, in the neighbourhood of the Lake of Ideo, in the middle portion of the same valley and in the upper portions of Val di Scalve and Val Seriana. The ores occur as veins in red grits of Lower Bunter age and in mica-schists of Carboniferous age: the gangue is generally quartzose, the average thickness 15 inches, and the content in metallic iron 45 per cent. On the other hand, in the formation known as *servino* (Upper Bunter), the ores occur rather as beds, three of which, averaging 4, 6 and 3¾ feet respectively have been worked in Val Trompia. They are, however, much faulted and in many places barren. The cost of extraction of the ores varies from 8s. 4d. to 12s. 6d. per ton, and their price delivered at the furnace ranges from 10s. to 33s. per ton. The Lombard blast-furnaces are of very small capacity and the fuel used is charcoal: a couple of blast-furnaces (as we know them in this country) would suffice to account for the annual ore-production of the entire province. This production at its possible maximum could not exceed 30,000 tons, and could never, therefore, form the basis of a staple industry. Moreover the variable, but generally high, price of imported coke is another adverse factor.

At the Castro and Tavernole works, efforts have been made to compete with British wrought-iron and sheet-iron, but these can be placed on the market at Genoa cheaper than the iron made in Lombardy. Similar attempts to manufacture steel by the Martin-Siemens process have been defeated by German imports. The only metallurgical industry, that appears nowadays likely to live in Lombardy, is the working-up of scrap-iron, etc., brought from elsewhere in the works at Dango, Castro, Carcina and Vobarno.

L. L. B.

## TESTING PITCH FOR BRIQUETTES.

*Apparat zur Prüfung von Pechsorten für die Briquettefabrication.* By OTTO BINDER. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 279-280, *and* 1 *figure.*

In most of the briquettes now made, pitch produced from tar by distillation in retorts is used to bind them. The quality of this tar, whether obtained from lighting-gas works, or from coke-ovens, and that of the coal from which it is made, vary greatly, and a testing-apparatus has long been wanted.

Pitch should contain very little ash, and in this respect does not need to be tested; its melting-point and viscosity are its most important characteristics when used for briquettes. It is generally considered sufficient to determine the quality of pitch from its melting-point, although, as it has really no definite melting-point, but passes gradually from a stiff to a soft and thence to a fluid condition, satisfactory results are seldom obtained. Hence the writer has invented a testing-apparatus, consisting of a small vertical cylinder, containing an inner hollow cylindrical tube, with six small openings into an outer tube where the heat is applied. It is surmounted by a ram, working up and down in a frame, exactly fitting into the inner tube. By means of a lever, fulcrum, and running weight, any given pressure upon the tube can be exerted and read off on a scale.

To make a test, the cylindrical tube is first heated by gas-jets or hot air, and the necessary temperature being attained, the pitch mixed with sand is placed in it, the ram pressed down, and a sample briquette thus manufactured. The mixture of sand and pitch must be first heated, and continually stirred; when black and well mixed the process is complete. If a strong thermometer be used to stir it, the proper temperature can be seen at a glance. Instead of sand, coal may be used, if care be taken that it is crushed to a uniform size. The writer tested mixtures of sea-sand containing from 3·8 to 9 per cent. of pitch. The briquette containing 5·6 per cent. was firm and smooth, those with a smaller percentage were less so, and as the percentage of pitch diminished they became looser and more brittle. The higher the percentage of pitch, the firmer, darker, and more polished were the briquettes. These results agree with those obtained in practice. An advantage of this method of testing is that the samples are of the same size, namely, 0·60 inch in diameter, and of the same consistency, and a standard is afforded for the different kinds of pitch. The briquettes may afterwards be fired on a small experimental grate, or tested in the heat of the sun for cohesion.

B. D.

## HEMINWAY PROCESS OF COKING COAL.

*Improved Heminway Process of coking Coal in Beehive Coke-ovens as used at the Plant of the Universal Fuel Company.* By DR. R. S. MOSS. *Mines and Minerals (Scranton, Pennsylvania)*, 1901, *vol. xxi., pages* 412-414, *with plans, sections, and illustration in the text.*

This improvement relates to the method of coking in a beehive-oven, and has for its object not only the production of a good sound metallurgical coke from so-called non-coking coals, but also improvement in the practice of coking generally. The writer considers it possible to obtain good results from coke whose structure is not exactly similar to the recognized form, and also to alter the cell-structure at will by intelligent manipulation during the time of coking.

It is known that whilst the ordinary Heminway method increases the

rapidity of combustion, yet the coking is uneven, the upper layers of coke getting burnt whilst one is waiting for the lower layers to coke. To overcome this and other difficulties met with in the Heminway process, the writer has made various improvements. Instead of blowing air from an opening having the pipe-diameter, the exit is enlarged by making it of an elliptical shape, raised slightly on the lower side instead of horizontal, thus blowing the air in a slightly upward direction into the oven and at a height above the mass of coal sufficient to protect it against combustion of the fixed carbon by a cushion of volatile matter between the coal and the air-supply. At a point at least 3 feet distant from the centre of the air-exit, a second air-supply, also elliptical in shape, is placed in an almost horizontal plane, thus completing combustion of the volatile matter escaping the lower air-supply. This form of exit ensures a better and more even mixture of air and combustible gas. Of course, this arrangement by itself would, by reason of the increased heat above the coal, only aggravate the trouble met with in the Heminway process. To meet this difficulty, the writer builds a flue from the inside of the oven just below the trunnel-head, carrying it down the outside of the oven and under the bottom, starting near the front, continuing along the bottom of the back, and again passing outside to a main flue built between the ovens. Twelve flues built under the oven equalize the heat from front to back, and by carrying the waste-gases from the top to underneath the floor, the temperature from top to bottom is more nearly equalized; the evolution of the volatile matter from the lower layers is increased, and the increased combustion required for these gases is obtained by opening the valves connected with the air-supply. This increased combustion in turn gives an increased quantity of heat, and thus the time of coking is reduced, whilst a more even coke, and one entirely free from black ends is obtained.

It is an advantage to build a double floor on the bottom of the oven to retain the heat, and one must also build the flue-floors of sufficient thickness to prevent undue loss of heat below. A yet more intimate mixture of air and gases is obtained by adding four openings in the oven on a level with and in favour of the one lower oval opening, and in such a manner that lines drawn from the lower sides of the openings will strike a point in the oven just below the trunnel-head. If necessary, two more openings may be added in favour of the one upper opening, these being directly opposite each other and almost horizontal with the face of the oven. But even in this case, in itself a great advance on the original method, we have an oven hottest at the top, cooler at the bottom, and coolest in the centre. To overcome this, the writer has arranged to pass air, waste-gases, or both together, under the bottom and up through the mass of coal in the oven by means of flues, or perforated tiles, or any arrangement that will allow the air or gases to pass up through the whole bottom of the oven. The importance of this perforated bottom cannot be overestimated, although like all other improvements, it can be made worse than useless by ignorant operation.

A battery of 24 coke-ovens on the foregoing lines has been erected and is producing results exceeding even the writer's own anticipations. Using duff-coal which costs 1s. 0½d. (25 cents) per ton at the mine, a 5 tons charge of so-called non-coking Illinois coal can be coked in 24 hours, and the coke is of superior quality. It is anticipated that with the perforated bottom, and intelligent management, the number of so-called non-coking coals will be further reduced, besides reducing the time of coking all coals now coked, coking a 7 tons charge in 36 hours equal to 72 hours coke, improving the quality and increasing the yield simultaneously.

X. Y. Z.

## REFRACTORY OR FIREPROOF MATERIALS.

*Feuerfeste Massen.* *By* Dr. — Steger. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, 1901, *vol. xlix., pages* 96-106.

The author points out that the industry which concerns itself with the preparation of refractory materials has undergone no startling changes of late years, for the reason that no fresh discoveries have been made in the way of raw material. On the other hand, continuous progress has been accomplished in regard to mechanical processes of manufacture, while the chemical side of the industry has been confined to the working-out of the ideas long ago mooted by such masters as Seger and Bischof.

*Magnesia-bricks.*—The difficulties connected with these are easily overcome, provided that the components which form the cementing-material exist at the outset in a very fine state of division. The best magnesites for such purposes are those that contain a sufficient percentage of cementing-material in the shape of iron-oxide, etc. (such as those of Styria), while purer magnesites cannot be kneaded at a white heat into sufficiently compact stone. Certain British and German processes are described whereby this difficulty is in some cases successfully overcome, and the use of electric furnaces now permits the liquefaction of alkaline earths hitherto regarded as unmeltable.

*Chromite-bricks.*—But if magnesites differ vastly in composition, still more so does chrome iron-ore, the raw material for chromite-bricks, as shewn by the 27 chemical analyses tabulated by the author. The best raw material for making such bricks is that which contains the highest proportion of chromium oxide, as precisely this compound melts with extreme difficulty: the impurities present in the ore act very well as cementing-matter. Some American and German patents are described, mainly directed to the provision of this cementing-matter when it is not naturally present in adequate proportions. Chromite-bricks do not enjoy any great popularity, because the chrome iron-ore of even one locality varies to such an extent that an average fixed composition cannot be relied on, and this is a factor of capital importance in the manufacture of fire-bricks. Moreover the price of the brick is too high. At one time, it was used as a parting layer between magnesia and Dinas-bricks, but it has been found that the separating layer can be dispensed with, as good Dinas-bricks are not corroded by magnesia-bricks.

*Dinas-bricks.*—The chief quality expected of a high-class Dinas-brick is that it shall contain the largest possible amount of silica, and as this is precisely characteristic of the British article, the Dinas-bricks from England command the market. The addition of a certain amount of cementing-matter is a *sine qua non*, as silica is of itself a highly fusible substance. In this connection the author describes briefly certain British and German patents.

*Carborundum* has become recently known as a good refractory material: coal, silica and salt are fused together in an electric furnace, and produce a compound containing about 69 per cent. of silica and 30 per cent. of carbon. The price is high, and the material is largely used as a fireproof enamel: it is also proof against acidic corrosion. L. L. B.

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## PYRITIC SMELTING.

*The Province of Pyritic Smelting.* *By* Herbert Lang. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., pages* 589-590 *and* 617-618.

It has often been asked, and doubtless will often be asked again, what is the dividing-line between pyritic and ordinary blast-furnace smelting?

The writer states that it is very narrow and very clearly marked. The essential difference is that the pyritic furnace forms oxides from sulphides (in particular the oxide of iron from pyrite within the furnace) while the other does not. It is not the heat resulting from this effective breaking up of the sulphides which characterizes the process, for this may be obtained in other ways. Any means whatever of decomposing the sulphides inside the stack will be a part of pyritic smelting, even though applicable in a measure to systems running on the old plan. In fact, the mere change of the charge of an ordinary furnace may convert it into a pyritic furnace. And since the addition of a little silica to the charge, converts ordinary matting under common conditions into pyritic smelting, this fact alone is sufficient refutation of the notion that the pyritic process is not a general process applicable to almost all the conditions where the ordinary method is applicable, besides being applicable to many where the ordinary is not. The writer believes that the work of every ordinary furnace, with certain exceptions, could be done better by pyritic furnaces. The exceptions apply to furnaces run on charges deficient either in silica or combustible sulphides; charges very high in silica which require a very acid slag, may also be excepted, for such slags have not as yet been produced in this form of smelting, although they are often handled by means of the hot-blast, which hot-blast, however, does not necessarily imply pyritic smelting.

The principle involved in the acidity of the charge was discovered independently by several workers, including the writer, who will discuss the matter more fully hereafter. This principle is certainly designed to make its way into almost universal practice; it is one of the mainsprings of the pyritic process, inasmuch as by its aid cold-blast pyritic workers are able to effect a desirable concentration of their product. Hence, irrespective of the advantages or disadvantages of the hot-blast, we possess a means of concentrating the matter which belongs exclusively to the pyritic process, while at the same time it can be applied to the ordinary method without alteration of furnace, etc. In either case, the work partakes of the pyritic character, and the writer cannot perceive any hampering conditions which prevent the method from being considered a general one.

At the first introduction of the pyritic process, it was thought that the method was most applicable to heavy sulphide-ores containing little or no intermixed gangue-matter and having an abundance of sulphur and oxidizable metals. But experience has shown that the conditions of cost of fuels, fluxes, etc., overshadow the condition of the chemical composition of the charge. In the case of such a substance as iron-pyrites, whose combustion evolves vast stores of heat, but whose fusion generates large quantities of matte, the process succeeds best when the charge contains but one-third or 35 per cent. of pyrites. Charges may be made up of a vast variety of ores, sometimes totally without fluxes, and at other times with more flux than ore. A list of various charges is given, comprising examples taken from actual practice, showing that a wide range of materials has been subjected to the pyritic influences with success and profit. These experimental results prove, amongst other things, that in order to obtain high concentrations, the charges must be stiffened up with silica to the highest permissible extent.

The points of this valuable paper may be summarized as follows:—(1) The difference between cold-blast pyritic and ordinary matting consists only in the make-up of the smelting mixture; (2) the ordinary process can probably produce more acid slags, and so far as shown by present practice, more basic slags also, than the pyritic method; (3) the application of the hot-blast saves

fuel and increases the daily capacity of the pyritic furnace, but leaves the process still subject to the same limitations as regards the proportions of silica; (4) mixtures deficient in sulphides cannot be successfully treated by pyritic smelting, because they would produce no matte; (5) silica governs the concentration of pyritic charges, and mixtures deficient in silica cannot be properly concentrated in the pyritic way; (6) matte may be concentrated by fusion in the pyritic stack, but not in the ordinary; and (7) iron seems to pass into the pyritic slags as singulo-silicate; and lime seems to form bi-silicates, mainly or wholly, in the pyritic stack. X. Y. Z.

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## MODIFIED SIEMENS AND HALSKE PROCESS.

*The Extraction-plant of the Arlington Copper Company.* *By* A. VON ZWALUWENBERG. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi.*, *page* 661.

The copper-mine of the above company at Arlington, New Jersey, has attracted much attention lately, and is now nearly ready for operation. The ore consists of sandstone and shale impregnated with several compounds of copper. It is to be treated by a method varying little in principle from the Siemens and Halske process, but differing considerably in the method of manipulation. The ore will first be fed into a large Comet crusher, then dried by heat from the waste-gases of the roasting furnace, then rolled, then pulverized, and then elevated to the feed-hopper of a Brown straight-line roasting-furnace. The principal object of the roasting is not the removal of sulphur, the ore not being expected to average more than 5 per cent. of this element, but to render some of the iron insoluble, and to effect other changes in the material necessary to successful lixiviation. While still hot, the roasted material will be charged into circular leaching-tanks, 30 feet in diameter, in which the copper will be extracted by the action of a solvent consisting originally of dilute sulphuric acid, but, after being used for some time, containing considerable ferric sulphate. The solution containing the dissolved copper will be subjected to electrolysis, the copper being obtained in metallic form and ferric sulphate regenerated at the anode, thus rendering the liquor available for the extraction of copper from a fresh portion of ore. Practical results of this new process are awaited with considerable interest.

X. Y. Z.

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## ACTION OF NATURAL IRON SULPHIDES AND NATIVE SULPHUR ON COPPER AND SILVER AT ORDINARY TEMPERATURES.

*Chemische Reaction der natürlichen Eisensulfide und des gediegenen Schwefels an Kupfer und Silber bei gewöhnlicher Temperatur.* *By* J. STRÜVER. *Centralblatt für Mineralogie, Geologie, und Palaeontologie*, 1901, *pages* 401-404.

All the experiments here described were repeated several times, in order to eliminate possible errors, and all the operations were conducted in a dark room.

Ordinary pyrites acts slowly, but marcasite and magnetic pyrites produce immediate blackening of the two metals (silver and copper). No action whatever has been observed in the case of platinum, lead, zinc, tin, iron, steel, nickel, antimony or bismuth. All these metals too, including silver and copper, are unaffected by the presence of either cobaltites, arsenical pyrites, antimony-glance or orpiment.

One condition of comparatively rapid action appears to be the presence of compounds rich in sulphur, an inference supported by the fact that native sulphur itself acts with greater energy and rapidity than any sulphur-compound on silver and copper, though not on the other metals enumerated above. It is sufficient to place a crystal or a fragment of sulphur on a small sheet of silver or copper to produce immediate blackening, and in the course of a few hours a crystalline uniform black film spreads over the whole of the metallic surface in contact with the sulphur, whence it extends gradually in all directions. The author points out that the metals from which he has obtained positive results are just those which in nature form by preference sulphides of the formula $M_2S$. Experiments made respectively with a well-cleaned gold coin and sulphur, and with mercury and sulphur, yielded negative results.

On a sheet of lead, well cleaned and polished, was laid a crystal of native sulphur. After a few days the whole surface (except the portion covered by the crystal) became dull, and this portion retained its lustre for several weeks. The author also experimented with native arsenic on copper and silver, but its contact with these metals yielded no visible results.

It is permissible to conclude that sulphur combines directly with the silver and copper, forming a crystalline compound; while in the case of the natural iron sulphides, the contact of silver or copper initiates a process of dissociation, the final result of which is the combination of a certain amount of freed sulphur with the silver or copper. L. L. B.

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## SILVERED *VERSUS* PLAIN COPPER PLATES.

*Electro-silvered versus Plain Copper-plates.* *By* JAMES R. COOPER. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., page* 330.

The difference in economy between plain copper and silvered plates depends entirely on the purity of the copper used in the plain plates. The principal impurity that causes trouble is oxygen. It is understood by gold-millers that the softest copper is the best for amalgamated plates: other things being equal, the copper which carries the least oxygen is the softest, and the writer is of opinion that a deoxidized copper-plate can be produced which is equal in every particular to a silvered plate. X. Y. Z.

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## AGITATION-PROCESS FOR CYANIDING SLIMES.

*The Agitation-process for Cyaniding Slimes.* *By* CHARLES S. HURTER. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., pages* 82-83, *with* 2 *illustrations.*

The problem that presented itself to the Cochiti Gold-mining Company, Bland, New Mexico, was how to treat successfully a low-grade slime without going to too great expense. After a trial of various processes, it was decided to use as an agitator a mixture of steam and compressed air. The agitation-tank (described fully in the original text) takes a charge of 3 or 3½ tons of pulp and 6 tons of solution. The steam and air pass first into a 3 inches distributing pipe, and from it to 1 inch pipes that pass through the tank as close to the bottom as possible. These pipes are placed 6 inches apart, and have perforations on the underside at 6 inches intervals, thus giving an even agitation all over the tank. Compressed air alone was at first used,

but the pipes clogged, and the solution became too cold to give a good extraction of values in a reasonable length of time. The air is delivered to the 3 inches pipe at a pressure of about 60 pounds per square inch, and the steam at about 30 pounds. Twenty-four hours are sufficient to extract 94 per cent. of the total values, using a solution of 3 pounds of cyanide of potassium to the ton. However, it was only possible to recover 80 per cent. without filter-presses, which could not be used on account of the expense. About 60 pounds of lime are suspended at the surface of the solution in a bucket of coarse-wire screen. A large excess of lime is used, because in addition to neutralizing any acidity in the ore, the effect is to make the slimes settle much more quickly in the settlers. By these means and proper sluicing, etc., enough gold and silver is recovered to bring the total extraction up to 80 per cent. The expense of recovering the remainder would exceed the profit. By this process, the total cost of treatment is 4s. 2d. (1 dollar) per ton of pulp treated. The advantages of the steam-and-air method over mechanical agitation consist of the absence of machinery, belts, etc., the small amount of repairs needed, and the small amount of power (0·1 horsepower per ton per day) required to secure perfect agitation. X. Y. Z.

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## CYANIDING STAMP-MILL TAILINGS IN WESTERN AMERICA.

*Cyaniding Stamp-mill Tailings in Western America: A Description of the Dexter Gold-mining Company's Plant at Tuscarora, Nevada.* *By* WM. MAGENAU. *Mines and Minerals (Scranton, Pennsylvania)*, 1901, *vol. xxi., pages* 299 301, *with* 1 *figure in the text.*

The Dexter Gold-mining Company of Salt Lake City, Utah, has a plant at Tuscarora, in Elko County, Nevada, which may be called a typical western plant, whilst yet possessing some novel features. The plant treats tailings from a 40 heads stamp-mill. The ore carries 85 per cent. of silica and 10 per cent. of iron. The richer ore carries much clayey material, requiring the use of much water in the stamp-batteries. Each of the settlers (designed to separate the sands from the slimes) is fitted with a Butters-and-Mein automatic revolving distributor, an appliance first used in South Africa, 7 years ago. It consists of a number of radiating 2 inches pipes of various lengths, centreing in an inverted cone-shaped receiver mounted on bearings at the tank-centre; the stream of tailings being discharged into the receiver finds outlet through the radiating pipes, each of which is bent to a right angle a few inches from the end. The reaction of the discharge from the pipes causes the whole appliance to revolve, distributing the material uniformly through the water-filled tank. In a correctly designed plant, the overflow from the tank, carrying with it the slimy portion of the tailings, goes into an annular trough, thus giving the largest possible cross-section to the overflowing stream and carrying out the minimum quantity of sand. A settler having been filled and drained, its contents are trammed into the leaching department. It is found that a 5 days' leach gives the maximum average extraction. The system of continuous percolation is used; there is but one strength of solution and but one set of solution-pipes. The drain-cocks below the filter-bottoms are left wide open, and the solution is run in on the top as fast as it will run through the charge. A novel feature here observed is the mode of adding the cyanide required to keep the solution at standard strength. This ore uniformly consumes 1½ pounds of cyanide of potassium per ton treated, and that quantity of cyanide per ton

of ore in a tank ready for its first wetting with solution is placed in a perforated tin tray 24 inches square and 6 inches deep. This tray is placed on top of the ore-charge under the pipe admitting solution, and the flow of the latter is started at such a rate that the ore is submerged at just the time when all the cyanide is dissolved. This plan was introduced to allow for the varying amounts of moisture retained in the sands; it ensures a full strength of solution at the commencement of leaching, and works well on this very uniform material. Formerly, the leached and washed residues were removed by shovelling through bottom-holes into cars beneath. Now, water-pressure being available, V shaped sheet-iron launders are placed under the tanks, and residues are sluiced out by means of a hose and nozzle. With a water-pressure of 60 pounds per square inch, one man can sluice out 50 tons in 1½ hours. The precipitation-department is adjacent to, and below the level of, the leaching-tanks; the pregnant solution flows directly into the zinc-boxes, practically no intermediate tank being used. Ten rows of zinc-boxes each with ten compartments, measuring 12 inches by 12 inches by 10 inches, are used. The entering solution carries 0·97 ounce of silver and 0·082 ounce of gold per ton; flowing through the loosely-packed boxes at an approximate rate of 3·1 tons per hour, it leaves with 0·1 ounce of silver and 0·01 ounce of gold, or 88·7 per cent. is precipitated. Considering the low grade of the entering solution, and the careless way in which the zinc-shavings are distributed, this seems remarkably good work, and is, in fact, quite contrary to what the writer's previous experience would have led him to expect.

The Bull Run Mining Company is also erecting a cyanide-plant, designed to get a quick extraction of values by agitation and by use of the combined decantation and vacuum-filter systems, and to handle the tonnage more economically than can be done when sand and slimes receive separate treatment.

X. Y. Z.

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## SADTLER PROCESS FOR TREATING ZINC-BEARING ORES.

*The Sadtler Process for treating Zinc-bearing Ores.* *By* BENJAMIN SADTLER. *The Engineering and Mining Journal (New York)*, 1900, *vol. lxx., pages* 368-369.

There is a large amount of zinc-ores carrying precious metals, which have been excluded from treatment in ordinary precious-metal smelters on account of its choking them, as well as rendering the slags less fusible and causing them to retain a larger proportion of precious-metal values. Such ores, also, would not work in ordinary furnaces for zinc-distillation, because, as a rule, they contain so much iron and lead as to make them corrode and destroy the retorts. This is mainly due to the fact that the characteristic zinc-product of the precious-metal mines is of the variety known as marmatite, containing so much iron as a component part that it cannot be separated by any of the usual magnetic processes.

After numerous experiments, the writer succeeded in preparing retorts with a thin basic lining which resists corrosive action, enabling him, after roasting the ore, to distil off the zinc and save it, and to leave the gold, silver, copper and iron-ores in the residue, also about 80 per cent. of the lead. This residue, being oxidized and containing some carbon and about 5 per cent. only of the zinc left in it, is desirable to precious metal-smelters and readily smelted by them at low expense.

In order to test thoroughly the resistance of the retorts to corrosion, two separate runs of 89 and 42 days were made. Both tests were entirely satisfac-

tory. In the first test, a small furnace, containing 30 full-size retorts, lined with various basic ingredients, was used, and after being carefully fired up in the furnace was charged with ore. During the run, 10 retorts were lost by breakage, but none were corroded. The breakages were chiefly due to the inexperience of the workmen. This gave a daily loss of one in 267 against the daily loss in Missouri, running on ores containing no appreciable quantity of iron, of 3 per cent. The ore treated in this case was very different from Missouri ore, in which it was their rule to place in the retort a charge containing not more than 2 per cent of iron, or 3 per cent. of lead, the loss by corrosion otherwise being too rapid. The ore treated in this test, however, ran, in the raw ore, from 16 to 30 per cent. of iron, from 1½ to 13 per cent. of lead, from 2 to 9 per cent. of silica, and from 16 to 37 per cent. of zinc. The silver ran from 5 to 17 ounces, and the gold from 4s. 2d. to 45s. 10d. (1 to 11 dollars). The zinc produced showed no gold or silver, these metals appearing to remain entirely in the residue. It showed from 0·52 to 1·12 per cent. of lead and from 0·06 to 0·12 per cent. of iron, both of these impurities being well within the limit allowed by first-class spelter. The residue was perfectly oxidized, containing some little carbon and all the gold, silver, copper and iron present in the ore and practically the whole of the lead. It contained from 4·2 to 8·5 per cent. of zinc on the smelter returns. As rather dirty slack coal had to be used, the silica in the residue ran somewhat higher than would be the case in practice, where a washed, or a pure slack coal would, of course, be used. The spelter produced from the run was reported to be of good quality, and suitable for refining purposes.

After describing the second test, which was deemed equally satisfactory, and which dealt with several lots of ore and concentrates from Colorado and Montana, the writer deals with some comparatively minor details, and concludes by remarking that the cost of the process is simply that of ordinary zinc-roasting and distillation plus the cost of 4d. to 6d. (8 to 12 cents) each for lining the retorts, which is more than offset by the greater life of the retorts as above shown, and by the fact that the roasting is cheaper because there is no necessity to roast so closely. The profits come from the fact that these composite ores can be purchased more cheaply than the pure zinc-ores of Missouri and elsewhere, and the gold, silver, and other valuable metals in the residue make it a saleable and profitable product.

X. Y. Z.

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## FRASCH ELECTROLYTIC PROCESS FOR REFINING NICKEL.

*The Frasch Electrolytic Process for Refining Nickel.* ANON. *The Engineering and Mining Journal* (*New York*), 1901, *vol. lxxi., pages* 428-429, *with* 3 *illustrations of the apparatus.*

In a previous article,* this process for refining nickel was partly described, one of the advantages of this invention consisting in the simultaneous recovery of caustic alkali and the salts of metals from ores or matte.

To treat copper-nickel ore and matte, and bring the metals therein contained into solution, the matte is used for an anode in an electrolytic bath; a solution of an alkali-salt forms the electrolyte, and ordinary carbon or copper-cathodes are employed. Caustic soda and a solution of the corresponding salts of the metals forming the matte are obtained, the sulphur

* *Trans. Inst. M.E.*, 1899, vol. xix., page 556.

remaining as concentrated residuum. The metallic solution thus obtained is subjected to electrolysis in a series of baths, all having matte anodes, and, preferably, copper cathodes. The anodes consist of disintegrated matte and are arranged so that the electrolyte passes through the body of the anode through a suitable diaphragm, past the cathodes, and through an overflow on to the anode of the bath next in series, and so on through any desired number of baths. The least electropositive metal (in this instance, copper) represented in the electrolyte is deposited at the cathodes in the passage of the electrolyte past the cathodes, care being taken that the tension of the electric current does not greatly exceed the electrochemical requirements for copper, the solvent agent represented in the electrolyte as liberated dissolving a corresponding quantity of fresh metals from the metal-bearing anode of each bath. By the repeated deposition of copper only, and re-saturation with the compound metals of the anode, the electrolyte becomes more and more saturated with the other metals and impoverished in copper, until a point of saturation is reached convenient for the recovery of the metals other than copper. To remove the last quantities of copper retained therein, the electrolyte in its passage through the bath last in series is not allowed to pass the cathodes, but is made to circulate through the anode only and below a diaphragm, permitting only enough of the electrolyte to pass through the diaphragm as will ensure complete exhaustion of the copper still contained in the electrolyte at the cathodes. The solution derived from the cathode-section of the bath last in series then contains only nickel, iron and cobalt. The iron is removed by chemical treatment, and the nickel may be separated from the cobalt by electrolysis or by chemical means.

The nickel salt is formed by absorbing ammonia in a solution of a nickel salt (such as the sulphate or chloride) until the nickel is transformed into the corresponding ammonium salt. The nickel-ammonium salt thus obtained is of great purity, and may be directly employed for nickel-plating and other purposes. On present determination, its chemical formula is $Ni(NH_3)_2Cl_2+4NH_3$. It is purple in colour, crystalline and very hygroscopic. Precipitated, it forms a fine powder of minute crystals; dissolved to saturation in hot water, large crystals quadratic in form and sapphire in colour are formed on cooling. Exposed to dry air, part of its ammonia evaporates, and the colour changes to green. Exposed to moist air, it absorbs moisture, liquefies, and forms a dark green solution. It is readily soluble in water, forming a blue solution, and parting with some ammonia. Boiled in aqueous solution, a green precipitate is formed. The dry salt smells slightly of ammonia, and, if moistened, develops the odour strongly. It differs from the normal nickel-ammonium chloride or sulphate in the great excess of ammonia that it contains. X. Y. Z.

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## METHOD OF CONVERTING SALT INTO BRINE BY SATURATION.

*Eine andere Methode zur Aufsiedung vorzeitig an der Bruchgrenze angelangter Langwerker im Salzthone.* *By* PAUL SORGO. *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, 1899, *vol. xlvii., pages* 584-585, *with* 2 *illustrations in the text.*

The writer assumes that in some salt-mines the limit of production has been reached in a horizontal direction, but that there is still a considerable amount of salt to be extracted from the roof of the level. Here therefore a new working is started, the size of which depends on the amount of salt-

bearing rock, the angle at which the lower level can be worked with safety, and other conditions. This upper working may be excavated either by injection, or by blasting, or by both methods. In the first case, the dissolving solution is passed continuously through an open pipe, run off into a vat, and there allowed to settle; in the second, the rubbish and chippings from the excavations are left in the circular space surrounding the old workings, to support the new part. Before the water is admitted, the vats to receive the brine are carried up to the roof from which the salt is to be extracted. Both workings, the upper and the lower, are then filled with brine, and water is injected, either continuously or intermittently, according to the amount of salt in the rock. If the brine has to be run off while the work is proceeding, both workings should be filled afresh with saturated brine, up to the top of the roof, the water being allowed gradually to eat away the salt. The writer does not consider a shaft necessary to admit the water and brine: a small artificial salt-lake or pond will fulfil the purpose. Another writer says that both the brine-water, and that injected for dissolving the salt, should drain off along vertical lines previously determined. Sterile rock is not necessary for the salt-lake, it may be made in saliferous clay if proper care be taken. Unfortunately it has not yet been found possible to test this method in an actual salt-mine, but laboratory-experiments have given very good results. It is applicable to all salt-mines in mountainous regions, even if the rock be very much fissured. B. D.

## GAS-FIRED PORTLAND CEMENT.

*A New Portland Cement-mill in the Gas-fields of Kansas.* *By* G. P. GRIMSLEY. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., page* 205, *with* 2 *illustrations.*

For ten years, natural gas has been used in Kansas for household purposes, but its use for manufacturing has been limited. Within the past three years, the centre of zinc-smelting has been moved from the coal-fields to the gas-belt, and a number of brickyards have also been started. The first Portland cement in Kansas was made at the new mill in Iola, comprising four buildings constructed of steel, brick and cement. Two of these contain three No. 5 Gates crushers, 21 rotary kilns, and 42 Griffin grinding-mills. The others contain the physical and chemical laboratories, electrical headquarters, machine-shop, and store-room. About 1,000 tons of limestone and shale are used per 24 hours, giving a daily production of 3,500 barrels of cement.

Natural gas is used to drive the engines, to dry the material, and to burn the cement. There are six 300 horsepower gas-engines and three of of 150 horsepower. At present the aggregate horsepower used is 2,600, supplied by 13 gas-engines, using about 5,000,000 cubic feet of gas per day.

X. Y. Z.

## PRESERVATION OF BUILDING-MATERIAL.

*Préservation des Constructions en Métal, Bois ou Pierre.* *By* L. KIRSCH. *Revue Universelle des Mines, etc.*, 1901, *vol. liii., pages* 83-93.

A new paint that may be of any desired tint, called "Zonca," which is absolutely weather-proof and preserves every kind of material from the action of dry or damp heat, acids, and gases, is composed of 46 per cent. of

cementing substance and 54 per cent. of solid matters, for the most part constituted by zinc oxide, with traces of clay, iron, silica, sulphuric acid, lime and magnesia. This paint, after an exposure of 72 hours to a temperature of 100° Cent., only lost 1·02 per cent. of its weight, while it was neither cracked nor blistered when applied to vessels in which water was boiled for several hours. Possessing the consistency of ordinary oil-paint, with a slight smell of turpentine, zonca forms no deposit after standing for several months, while, laid on by an inexperienced hand, it produces a perfectly united surface without showing any brushmarks. The fresh paint can be exposed to the direct action of flame without taking fire; and a lighted match inserted therein is at once extinguished. The plunging of a red-hot iron bar into the paint only caused its surface to rise; and alcohol spread over it can be ignited without communicating the fire, this substance only becoming inflammable if heated above 180° Cent. J. W. P.

## BOILER-ACCIDENTS IN FRANCE IN 1899.

*Bulletin des Accidents d'Appareils à Vapeur survenus pendant l'Année* 1899. ANON. *Annales des Mines*, 1900, *series* 9, *vol. xviii.*, *pages* 516-545.

Of the 50 accidents dealt with in this exhaustive summary of official documents, 1 took place in a colliery, 1 in a metalliferous mine, and 6 in ironworks and other metallurgical establishments. The other 42 accidents are evenly distributed among factories dealing with various branches of industry, railway-shops, electric-power plant, and agricultural machinery.

The accident which occurred on August 10th, 1899, at the Ostricourt colliery, Pas de Calais, was caused by overheating of the boiler as a result of deficiency of water. The boiler had been purchased second-hand; the plates were 0·374 inch thick, and showed a rent some 6½ feet in length. The indicators of water-level consisted of a glass tube and a magnetic gauge with alarm-whistle. There is reason to believe that the magnetic indicator had been tinkered at, in such a way that the whistle would not sound. No injury to life or limb resulted from this accident.

On November 21st, 1899, two men sustained mortal injuries from the bursting of a boiler at the metalliferous mines of Pontpéan, Ille-et-Vilaine. The boiler was on the De Naeyer system, manufactured in 1891, and tested for the last time in September, 1893. It had been standing idle for a fortnight, and had been put in use again the day before the disaster; but was almost immediately stopped on account of leakages. The accident was due to the rupture of an anchor-bolt, which appears to have sustained an undue amount of jarring. The whole arrangement of the apparatus rather lent itself to an accident of the kind, and tended to heighten its disastrous effect.

With regard to the causes assigned for the whole of the 50 accidents, they are divided into three categories, and in 13 cases an accident is assignable to more than one of these categories. The first comprises defects in the setting or build of the boiler—13 accidents; the second, defective conditions of maintenance—19 accidents; and the third, bad usage of the apparatus—26 accidents. Moreover in 5 cases, the cause of the accident is not clearly determinable. With regard to bad usage, there are no less than 14 cases of superheating and 6 of excessive pressure. It is interesting to note that water-tube boilers are responsible for 14 out of the 50 accidents enumerated, with a loss of 7 lives, the total loss of life by these accidents in France in 1899 amounting to 25. Moreover 20 persons were seriously injured.

L. L. B.

## LOSS OF PRESSURE IN PIPES LEADING COMPRESSED AIR.

*Calcul de la Perte de Charge dans les Canalisations d'Air comprimé.* By A. HALLEUX. *Annales des Mines de Belgique*, 1901, *vol. vi., pages* 3-20, *with figures in the text.*

Independently of the scientific interest, there is practical importance in possessing the means for correctly calculating the loss of pressure in a line of pipes for leading compressed air, or better still, in being able to determine, for a given loss of pressure, the diameter of pipes required to transmit a given power. Hitherto, the formulæ employed or proposed for calculating the loss of load have been empirical; but the author considers that, basing his study on thermodynamics, he has arrived at a correct formula. When the difference of level between the beginning and end of an air-pipe is slight in comparison with its length he proposes the use purely and simply of the following formula, which will involve no error:—

$$p_2 = \sqrt{p_1^2 - \frac{2C.LP^2RT}{D.g.S^2}}$$

$p_1$ and $p_2$ being respectively the initial and final pressure in kilogrammes per square metre; C, the coefficient of friction of air on iron, found by calculation to be 0·0075; P, the weight of air passing per second expressed in kilogrammes; T, its absolute temperature in Centigrade degrees; R, the constant 29·27 found by Gay-Lussac for air; L, the length and, D, the diameter of the pipe in metres, and, S, its sectional area in square metres. If, however, the difference of level is considerable, the experimenter can, according to the importance of the power-transmission, either (1) employ the above formula, which will lead to a too slight value for the final pressure, or (2) calculate the pressure $p_2$ for the vertical member of the pipe-line by the same formula, and add to this value the increase of pressure due to the difference of level, which increase will be calculated under the supposition that the fluid is static.

J. W. P.

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## DANGER IN LUBRICATING THE CYLINDERS OF AIR-COMPRESSORS WITH RAPE-OIL.

*Gefahr bei der Rüböl-schmierung in Luftpresscylindern.* ANON. *Zeitschrift für das Berg-, Hütten- und Salinenwesen im Preussischen Staate*, 1900, *vol. xlviii., pages* 178-180.

On June 8th, 1899, two miners, who were engaged in boring shot-holes in the Concordia ironore-mine near Dermbach with a compressed-air drill, working under a pressure of 4 to 6 atmospheres, noticed a strong smell in the escaping air, and attempted to withdraw, but only one succeeded, the other being overcome by the foul air and dying on the spot. The cause of death was ascertained by the *post-mortem* examination to be carbon-monoxide poisoning. As an influx of this gas from the surrounding shale appeared impossible, attention was directed to the compressed air from the drill, more especially since a disagreeable smell, like burnt oil, accompanied by an irritant action on the eye, had been previously noticed by the miners. It was then ascertained that for several weeks the air-compressor cylinder had been lubricated with rape-oil, in the absence of the usual mineral oil; and it was found that, on reverting to the latter, the aforesaid smell ceased. This threw suspicion on the rape-oil, the inference being that the latter had suffered decomposition into acrolein, which in turn furnished carbon monoxide; and

to confirm this opinion tests were made in order to determine the temperature in the compressor-cylinder and the behaviour of the oil under the influence of heat. When distilled at the ordinary pressure at an average temperature of 89° Cent. neither the above oil (which was found to be adulterated with train oil), nor other crude and purified rape oils, yielded any weighable quantities of carbon monoxid', but on carrying out the distillation at higher temperatures and under pressure, the oil in question—at 166° Cent. and an excess pressure of 0·2 atmosphere—furnished 1·6 per cent. of carbon monoxide, and in the case of a purified oil the amount of this gas increased with the temperature and pressure, until at 291° Cent. and 1·3 atmosphere excess pressure, the percentage reached 5·8. Thus, the poisonous gas produced by the decomposition of the oil in the compressor-cylinder, had evidently accumulated in the poorly ventilated working-place in the Concordia mine, in sufficient quantity to prove fatal. C. S.

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## ELECTRIC WINDING-ENGINE.

*Charbonnage de la Nouvelle-Montagne, Siège Tincelle: Machine d'Extraction et Ventilateurs mus par l'Électricité.* *By* H. HUBERT. *Annales des Mines de Belgique*, 1901, *vol. vi.*, *pages* 173-175.

The winding-engine and a Guibal fan, 13 feet (4 metres) in diameter, are driven by electro-motors of 30 and 90 effective horsepower at the speed of 750 and 500 revolutions per minute respectively, supplied from two alternating-current dynamos each of 65 kilowatts, and a tension of 2,200 volts. The line, 6,500 feet (2,000 metres) long, connecting the Tincelle colliery with the generating-station, is composed of three hard copper wires of 0·024 square inch (16 square millimetres) sectional area. The electro-motor of the winding-engine is fitted with a starter and a reversing interrupter, which latter, consisting of two copper-plates on an insulated shaft, is capable of closing the circuit, in one or other direction, by the lifting of twelve spring-contacts, the plates and contacts for the various phases being separated by a glass plate. When the plates are in the vertical position the circuit is interrupted; and on turning the shaft right or left, by means of a lever on the outside, to the extent of 90 degrees, and by acting on the resistance, the electro-motor is made to revolve in the desired direction. The starter is composed of iron spirals contained in a perforated plate box, carrying on one of its sides an interrupter with horizontal axis, one and the same lever working the shafts of the starter and interrupter. When this lever is in mid-position, the primary and secondary currents are interrupted; and moving the lever in one direction closes the primary circuit, when the lever makes a slight lateral movement, leaves the interrupter, and engages with the starter, while further movement of the lever introduces resistance into the secondary circuit so that the motor takes on its normal speed. When the lever is brought back, the circuit is first interrupted and then re-established for working in the opposite direction, this arrangement preventing any mistake on the part of the engineman. It is arranged to wind, with one or other cage separately, or with both together, by two flat manilla ropes. J. W. P.

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## ELECTRICAL TRANSMISSION FROM COAL-MINES.

*Electrical Transmission from Coal-mines.* By FRED. WILSON HART. *Electrical World and Engineer (New York)*, 1901, *vol. xxxvii., pages* 345-349, *with* 7 *illustrations.*

While the transmission of power over long distances is not unusual where the source of power is water, very few attempts have been made to transmit electric power from plants located at coal-mines, and the following notes of one of the latest of these attempts are of interest. About 3 years ago, the Cochiti Gold-mining Company erected a large cyanide-mill at its Albemarle mine, Bland, New Mexico. A large Corliss engine was installed for driving the crushers, rolls, screens, etc., cord-wood being used for fuel. Owing to the rapid development of the mine, it became necessary about 2 years ago to increase the capacity of the mill, but the question of fuel was an important one. Wood-fuel was not only expensive, but the supply at the price was limited. To use coal was impracticable, as it would have had to be hauled by wagon for 25 miles over a rough mountainous country; and within a radius of 50 miles there was no water-power available. An examination was therefore made of the coal-deposits belonging to the Santa Fe Railroad at Madrid, New Mexico, and as the coal could be had at a nominal price, it was decided to install a modern steam-plant at Madrid and transmit the power electrically to the Cochiti Company's mine, a distance of 32 miles.

While the conditions of the comparative cost of fuels were favourable for the Cochiti plant, its isolated location, the rough mountainous country across which the pole-line had to be constructed, and the lack of feed-water of any kind at the coal-mines, made the cost of construction much greater than would be required for the average plant. The feed-water supply was the one point on which the success of the plant seemed to depend. The coal company at Madrid had, at times, to ship water in tank-cars a distance of 40 miles. This was not practicable for a power-plant, and a 4 inches pipe-line was therefore built from the power-house to the Galisteo river, a distance of 14,000 feet. The Galisteo is a typical Mexican arroyo in which 11 months of the year there is no sign of water on the surface, but which has a heavy underflow at a depth of 3 or 4 feet. A crib was built under the quicksand in which the water was collected, and a 48 hours' test demonstrated that a supply of 250,000 gallons per day could be obtained.

The pole-line is designed to carry eventually two circuits of No. 4 wire, the three wires of each circuit being placed at the points of an equilateral triangle, the distance between wires being 24 inches. The telephone-circuit of No. 12 hard-drawn copper is placed 5 feet below the power-circuits. The power-circuits are transposed every ½ mile, the telephone every 5 poles. No difficulty is experienced from induction on the telephone-circuit. The poles are spaced 100 feet apart, and under normal conditions are 28 feet long. But as the line crosses several arroyos at right angles, and for several miles is constructed through a narrow rocky cañon, poles varying from 20 to 40 feet long were sometimes used to reduce the strain due to vertical angles. At arroyos, subject annually to heavy floods, it was necessary to support the line on towers located on the banks as far as practicable above the water-level. These spans are about 400 feet long, and hard-drawn copper wire is used at such points. The energy lost in the line when delivering 600 kilowatts to the mine is 8½ per cent.

It was with great difficulty that a survey of the line could be made through the cañon alluded to, on account of its rough and precipitous sides;

and the construction of the line presented several obstacles, such as blasting holes in rock-ledges where there was hardly room for a man to stand; hauling poles with tackle several hundred feet up the sides of the cañon; material having to be carried on men's backs for long distances over sections where pack-mules were not available, etc. On one section, the heavy pine-timber made it necessary to clear a right of way for several miles, some 6,000 trees being cut down. An idea may be formed of the character of the country from the fact that there is but one point on the line where water can be obtained, and but one where there is a house within many miles.

The total cost of supplying power with the steam-plant, using cord-wood as fuel, hoisting and milling 200 tons per 24 hours was £45 8s. (218 dollars). The cost of doing the work with electric power generated at Madrid, and transmitted 32 miles, is £11 4s. (53¾ dollars) per day for hoisting and treating 300 tons, which is a half more ore than that handled by the old steam-plant. (These figures do not, in either case, include interest and depreciation). The saving made demonstrates that under favourable conditions electric power generated at coal-mines can be transmitted over long distances and successfully compete with steam-power. X. Y. Z.

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## DANGERS IN THE WITWATERSRAND MINES.

*The Preservation of Life in the Witwatersrand Mines.* By T. Lane Carter. *The Engineering and Mining Journal (New York)*, 1902, *vol. lxxiv., page* 279.

The dangers from running rock-drills in the Witwatersrand mines are considered under four heads:—

(1) *Dust.*—The writer believes that dust is the most fatal danger, and that it does not receive the blame which it deserves. In making out the annual mortality-returns, the indirect causes of death are seldom noted. The most unintelligent miner knows the dangers of a treacherous roof or of poor dynamite, but it seems impossible to make him realize the slow but sure dangers of dust. No doubt coal-miners live for years in atmospheres as dusty as those of the gold-mines; but the two kinds of dust are very different. Coal-dust is soft and friable, whereas quartzite-dust is exceedingly sharp and incisive. The miner works in this atmosphere of dagger-like dust for a long while, before he realizes the damage done to his constitution. When the dust settles on the lungs, cutting of the tissues commences, and after a while he begins to cough. The lacerated lung is unable to resist the bacteria of tuberculosis, and consumption, or "miners' complaint," carries him off.

Two remedies have been suggested:—(1) To prevent the formation of dust as much as possible; and (2) to compel the miners to use approved respirators. A small jet of water, playing on a dry hole, is proposed to prevent the dust rising from a drill at work. The very fine dust produced by blasting is more difficult to overcome: it settles all over the stopes, and is disturbed when the stuff is shovelled away. If the men could be forced to wear respirators always the difficulty would vanish. Some medical officers recommend that all white employees should be strictly compelled to wear them. This may be carrying the idea too far, but miners who run rock-drills in rises or drives should certainly be forced to use respirators at all times. Not so much attention is given to the Kaffirs as to the white miners, for the simple reason that scarcely any of them stay long enough at the mines to suffer from the adverse conditions.

(2) *Exposure.*—This is the next cause of the mortality among underground workmen. The climate necessitates the choice of the best wearing-apparel. Pneumonia is easily contracted, and is very dangerous. A miner will work in a close warm stope till he is dripping with perspiration, and then stand near the exhaust-pipe of a rock-drill in order to cool down, and one cannot wonder that pneumonia attacks him. The more careful miners wear good woollen underclothing and warm sweaters all the year round.

(3) *Falls of Rock.*—These are responsible for comparatively few deaths. As a rule, the hanging-walls are all that can be desired, requiring little or no timber, but only an occasional pillar here and there. The generality of this rule is one of the wonderful things about mining in this country. In places, however, where the roof is really bad, the best practice is to leave pillars in the stopes and not to build pack-walls after the material is all removed, for no matter how carefully the packing is done, it never answers as well as a pillar left *in situ*.

(4) *Explosives.*—The number of accidents from the use of explosives would be reduced almost to *nil*, if sufficient care were exercised by the miners. As a general rule, this class of accident occurs either through sheer carelessness on the part of the miner, or to undue eagerness on his part to get back to the working-face after a blast.

The dangers of mining are practically confined to the underground work. Notwithstanding the deadly nature of the potassium-sodium-cyanide solutions, accidents in the cyanide works are remarkably few. This immunity is largely due to the practice of placing the cyanide tanks out in the open air, and keeping the solution-sheds well ventilated, so that all danger from hydrocyanic acid gas is completely avoided. X. Y. Z.

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## MINING LAW IN TURKEY.

*The Minerals of the Ottoman Empire.* *By* H. R. JASTROW. *The Engineering and Mining Journal (New York)*, 1901, *vol. lxxi., pages* 620-621.

Although the mineral resources of the Ottoman empire are both rich and various, their development is, for a number of well-known reasons, very limited. The greatest hindrance is possibly found in the many government restrictions imposed. For example, the right to exploit a mine must be secured through a royal *irade*, the request for which must be accompanied by an application for a permit to prospect. The prospector must guarantee his responsibility for all damages inflicted, and some responsible person must be bond for the fulfilment of this guarantee. The privilege of prospecting is granted for a period not exceeding 2 years, while the final concession for the exploitation of chrome, manganese and other ores is granted for a period of 99 years. Every mine must pay a ground tax of about 10d. per acre (10 piastres per hectare); and, on the exportation of lead, copper, antimony, zinc, etc., the Government claims 5 per cent. of the value, and 1 per cent. export-duty. Chrome and manganese-ores and borax pay a tax of 15 per cent., and 1 per cent. export-duty. On all ores from the mines of Balia, however, a rebate of 3 per cent. is allowed. The holder of a prospecting permit has further the privilege of exporting up to 100 tons of ordinary ores, and up to 2,000 tons of chrome-ore and manganese-ore as sample shipments without payment of tax, but must deposit, as guarantee of his good intentions, double the regular tax, which is refunded to him when the ores leave the country.

X. Y. Z.

# II.—BAROMETER, THERMOMETER, ETC., READINGS FOR THE YEAR 1901.

By M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of Glasgow and Kew Observatories, and give some idea of the variations of atmospheric temperature and pressure in the intervening districts in which mining operations are chiefly carried on in this country.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometrical readings at both observatories are reduced to 32° Fahr.

The statistics of fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are also printed upon the diagrams (Plates XXXV. and XXXVI.) recording the meteorological observations.

The times recorded are Greenwich mean time, in which midnight equals 0 or 24 hours.

TABLE I.—SUMMARY OF EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1901.

| Mines-inspection Districts. | Fatal Accidents. | | | Non-fatal Accidents. | |
|---|---|---|---|---|---|
| | No. | Deaths. | Injured. | No. | Injured. |
| Cardiff ... ... ... | 5 | 95 | 12 | 5 | 5 |
| Durham ... ... ... | 2 | 2 | 3 | 1 | 2 |
| Ireland ... ... .. | 0 | 0 | 0 | 1 | 2 |
| Liverpool ... ... .. | 1 | 4 | 0 | 0 | 0 |
| Manchester ... ... | 1 | 4 | 10 | 2 | 2 |
| Midland ... ... ... | 0 | 0 | 0 | 7*† | 9 |
| Newcastle-upon-Tyne ... | 0 | 0 | 0 | 8 | 12 |
| Scotland, East ... ... | 0 | 0 | 0 | 29 | 46 |
| Do. West ... ... | 5 | 7 | 7 | 33† | 45† |
| Southern ... ... ... | 1 | 2 | 3 | 2 | 6 |
| Staffordshire, North ... | 2 | 6 | 0 | 3 | 4 |
| Do. South ... | 1 | 2 | 1 | 9 | 9 |
| Swansea ... ... ... | 2 | 2 | 10 | 11 | 15 |
| Yorkshire ... ... ... | 1 | 1 | 1 | 9† | 10 |
| Totals ... ... | 21 | 125 | 47 | 120*† | 167† |

* Including an explosion by which no persons were injured.
† These figures do not agree with those recorded in *Mines and Quarries; General Report and Statistics for 1901*, part I., pages 28 and 29.

TABLE II.—LIST OF FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1901.

| 1901. | Colliery. | Mines-inspection Districts. | Deaths. | No. of Persons Injured. |
|---|---|---|---|---|
| Jan. 16, 12·0 | Ystradgynlais ... .. | Swansea ... ... | 1 | 4 |
| ,, 23, 8·0 | Kirkwood.. ... ... | Scotland, West ... | 1 | 0 |
| ,, 25, 7·45 | Haughhead ... ... | Do. ... | 2 | 3 |
| ,, 27, 22·0 | Holytown (No. 8 Pit) ... | Do. .. | 1 | 0 |
| Feb. 28, 12·30 | Blaendare Slope ... ... | Southern ... ... | 2 | 3 |
| Mar. 25, 7·0 | Dinas (Old Level) ... | Cardiff ... ... | 4 | 2 |
| April 1, 17·30 | Sandbach ... ... ... | Staffordshire, North | 2 | 0 |
| ,, 10, 7·30 | Orrell ... ... ... | Liverpool ... ... | 4 | 0 |
| May 6, 13·0 | Tursdale ... ... ... | Durham ... ... | 1 | 2 |
| ,, 16, 7·15 | Gilmilnscroft (No. 3 Pit) | Scotland, West ... | 1 | 3 |
| ,, 24, 5·10 | Universal ... ... ... | Cardiff ... ... | 81 | 1 |
| ,, 27, 19·30 | Talk-o'-th'-Hill ... ... | Staffordshire, North | 4 | 0 |
| June 26, 17·0 | Meiros ... ... .. | Cardiff ... ... | 1 | 5 |
| July 8, 6·30 | Stoneclough ... ... | Manchester ... ... | 4 | 10 |
| ,, 20, 11·0 | Fochriw ... ... ... | Cardiff ... ... | 1 | 2 |
| Aug. 19, 23·15 | Hamstead ... ... | Staffordshire,South.. | 2 | 1 |
| ,, 26, 8·30 | New Dale ... ... ... | Yorkshire ... ... | 1 | 1 |
| Sept. 10, 17·25 | Llanbradach ... ... | Cardiff ... ... | 8 | 2 |
| ,, 18, 15·45 | Pencoed ... ... .. | Swansea ... ... | 1 | 6 |
| Nov. 12, 17·0 | Edmondsley ... ... | Durham ... ... | 1 | 1 |
| Dec. 9, 7·45 | Cornsilloch (No. 3 Pit) ... | Scotland. West ... | 2 | 1 |
| | | | 125 | 47 |

TABLE III.—LIST OF NON-FATAL EXPLOSIONS OF FIRE-DAMP OR COAL-DUST IN COLLIERIES IN THE SEVERAL MINES-INSPECTION DISTRICTS DURING 1901.

| 1901. | Colliery. | Mines-inspection Districts. | No. of Persons Injured. |
|---|---|---|---|
| Jan. 14, 0·15... | Bebside ... ... ... | Newcastle-upon-Tyne | 1 |
| ,, 15, 10·30... | Roman Camp (Oil-shale) . | Scotland, East ... | 1 |
| ,, 21, 11·0 ... | Shut End ... ... ... | Staffordshire, South ... | 1 |
| ,, 23, 7·45... | Redburn (No. 1 Pit) .. | Scotland, West .. | 1 |
| ,, 29, 4·0 .. | Newfield ... ... ... | Durham ... ... | 2 |
| ,, 29, 21·30... | Blantyre Ferme ... ... | Scotland, West ... | 1 |
| ,, 30, 0·30... | Crigglestone ... ... | Yorkshire ... ... | 1 |
| ,, 30, 6·15... | Hartshay ... ... ... | Midland ... ... | 1 |
| ,, 30, 7·45... | Montgomerie-field (No. 2 Pit) ... ... ... | Scotland, West ... | 1 |
| ,, 31, 6·30 .. | Wallyford ... ... ... | Scotland, East ... | 1 |
| ,, 31, 14·15... | Monkland ... ... ... | Do. ... .... | 1 |
| Feb. 4, 9·30... | Ravenshall (No. 43 Pit) ... | Scotland, West ... | 1 |
| ,, 5, 11·30... | Caprington (No. 40 Pit) ... | Do. ... | 2 |
| ,, 13, 9·0 ... | Gospel Oak ... ... ... | Staffordshire, South ... | 1 |
| ,, 14, 8·0 ... | Bradley ... ... ... | Do. ... | 1 |
| ,, 15, 7·0 ... | Corby Craigs (No. 4 Pit) . | Scotland, West ... | 2 |
| ,, 15, 8·0 ... | Walsall Wood ... ... | Staffordshire, South .. | 1 |
| ,, 15, 22·0 ... | Bradley ... ... . | Do. ... | 1 |
| ,, 19, 9·30... | Sandbach ... ... ... | Staffordshire, North ... | 1 |
| ,, 24, 23·0 ... | Pildacre ... ... . | Yorkshire ... ... | 1 |
| ,, 25, 8·0 ... | Jarrow ... ... ... | Ireland... ... ... | 2 |
| ,, 25, 10·30... | Fergushill (No. 23 Pit) ... | Scotland. West ... | 1 |
| Mar. 1, 8·0 ... | Quarry House ... .. | Yorkshire ... ... | 1 |
| ,, 1, 13·0 ... | East Holywell ... .... | Newcastle-upon-Tyne | 1 |

TABLE III.—*Continued.*

| 1901. | | Colliery. | Mines-Inspection Districts. | No. of Persons Injured. |
|---|---|---|---|---|
| Mar. | 2, 6·30... | West Silkstone ... ... | Yorkshire ... ... | 1 |
| ,, | 2, 7·15... | Glencraig ... ... ... | Scotland, East .. | 2 |
| ,, | 2, 8·0 ... | Braichycymmer, Darran ... | Swansea ... . | 2 |
| ,, | 5, 8·30... | Gelynog ... ... ... | Cardiff... ... .. | 1 |
| ,, | 7, 6·0 ... | Stoneclough ... ... | Manchester ... .. | 1 |
| ,, | 13, 12·30... | Bridgeness ... ... ... | Scotland, East ... | 1 |
| ,, | 13, 4·30... | Fochriw ... ... ... | Cardiff... ... ... | 1 |
| ,, | 15, 14·30... | Whitfield ... ... .... | Staffordshire, North .. | 2 |
| ,, | 18, 16·0 .. | Glynea ... ... ... | Swansea ... ... | 1 |
| ,, | 20, 6·30... | Farme (No. 3 Pit)... ... | Scotland, West .. | 1 |
| ,, | 20, 7·15 . | Whitehill (No. 1 Pit) .. | Do. ... | 1 |
| ,, | 21, 22·30... | Kinniel ... ... ... | Scotland, East . | 3 |
| ,, | 22, 13·0 ... | Cadder (No. 17 Pit) ... | Scotland, West .. | 3 |
| ,, | 24, 3·30... | Crigglestone ... ... | Yorkshire ... . | 1 |
| ,, | 29, 0·10... | Seaton Burn ... ... | Newcastle-upon-Tyne | 2 |
| ,, | 30, 9·0 ... | South Wales ... ... | Southern ... ... | 2 |
| April | 1, 7·0 ... | Dalmeny (Oil-shale) ... | Scotland, East . | 1 |
| ,, | 1, 17·15... | Walkinshaw (No. 2 Pit) ... | Scotland, West . | 1 |
| ,, | 3, 8·0 ... | Meiros ... ... ... | Cardiff... ... ... | 1 |
| ,, | 17, 7·30... | Caerbryn ... ... .. | Swansea ... ... | 1 |
| ,, | 24, 16·30.. | Blindell's Black Vein (Glyn) | Southern ... ... | 4 |
| May | 2, 8·30... | Orbiston (No. 2 Pit) ... | Scotland, West ... | 3 |
| ,, | 4, 11·0 ... | Pantycelyn ... .. | Swansea ... ... | 1 |
| ,, | 5, 23·0 ... | Kippax ... ... ... | Yorkshire ... .. | 1 |
| ,, | 7, 9·0 ... | Newliston (Oil-shale) .. | Scotland, East .. | 1 |
| ,, | 15, 22·30... | High Hazels ... ... | Yorkshire . ... | 1 |
| ,, | 31, 6·45... | Bridgeness ... ... ... | Scotland, East ... | 2 |
| June | 1, 0·30... | Glencraig ... ... .. | Do. ... | 2 |
| ,, | 4, 9·30... | New Hermand (Oil-shale) | Do. ... | 2 |
| ,, | 4, 20·20... | Lanemark (No. 2 Pit) ... | Scotland, West ... | 2 |
| ,, | 10, 10·0 ... | Philpstoun (Oil-shale) ... | Scotland, East ... | 1 |
| ,, | 11, 12·0 ... | Victoria (No. 2 Pit) ... | Scotland, West .. | 1 |
| ,, | 12, 12·0 ... | Kenmuirhill (No. 2 Pit) .... | Do. .. | 1 |
| ,, | 17, 10·0 ... | Lanemark (No. 2 Pit) .. | Do. ... | 1 |
| ,, | 21, 9·30... | Glencraig ... ... ... | Scotland, East .. | 1 |
| ,, | 24, 7·10... | Sutton ... ... .... | Midland ... . | 1 |
| ,, | 25, 6·30... | Farme (No. 3 Pit) ... ... | Scotland, West .. | 1 |
| ,, | 26, 8·0 ... | Calder ... ... ... | Yorkshire ... ... | 2 |
| July | 2, 15·0 ... | Bannockburn (No 2 Pit) .. | Scotland, West .. | 1 |
| ,, | 3, 4·0 .. | Oakbank (Oil-shale) ... | Scotland, East .. | 1 |
| ,, | 4, 18·30... | East Holywell ... . | Newcastle-upon-Tyne | 1 |
| ,, | 12, 2·0 ... | Coedcae ... ... .. | Cardiff... ... .. | 1 |
| ,, | 15, 9·30 .. | Montgomerie-field (No 2 Pit) | Scotland, West .. | 1 |
| ,, | 19, 14·50... | Swanwick ... ... ... | Midland ... .. | 1 |
| ,, | 28 ... | Clay Cross ... ... ... | Do. ... ... | 0* |
| ,, | 29, 15·30.. | Oakwood (No. 27 level) .. | Swansea ... ... | 1 |
| ,, | 30, 11·0 ... | Stanrigg ... .. | Scotland, East ... | 2 |
| Aug. | 5, 14·0 ... | Forkneuk (Oil-shale) .. | Do. .. | 1 |
| ,, | 6, 5·0 ... | Woodhall ... ... .. | Scotland, West ... | 1 |
| ,, | 6, 6·15... | Chickenly Heath ... .. | Yorkshire ... ... | 1 |
| ,, | 8, 7·30... | West Sleekburn ... .. | Newcastle-upon-Tyne | 1 |
| ,, | 13, 19·0 .. | Bank (No. 1 Pit) ... .. | Scotland, West .. | 1 |
| ,, | 22, 15·20. | Westburn (No. 2 Pit) . | Do. ... | 1 |
| ,, | 24, 7·40... | Fishley ... ... ... | Staffordshire, South ... | 1 |
| ,, | 26, 6·0 ... | Monkland ... ... ... | Scotland, East .. | 1 |
| ,, | 26, 7·20... | Stanrigg ... ... ... | Do. ... .. | 6 |
| ,, | 26, 7·45... | Highhouse (No. 1 Pit) .. | Scotland, West .. | 1 |
| ,, | 26, 11·0 ... | Foxley (No. 3 Pit) ... | Do. ... .. | 2 |
| ,, | 30, 1·0 ... | Tirydail ... ... ... | Swansea ... ... | 2 |
| Sept. | 3, 14·0 ... | North Elswick ... .. | Newcastle-upon-Tyne | 2 |

* This explosion was due to electricity, and occurred on Sunday when no one was in the mine.

TABLE III.—*Continued.*

| 1901. | Colliery. | Mines-inspection Districts. | No. of Persons Injured. |
|---|---|---|---|
| Sept. 6, 20·0 ... | Glencraig ... ... ... | Scotland, East ... | 1 |
| ,, 12, 11·30... | Norton Cannock ... ... | Staffordshire, South ... | 1 |
| ,, 13, 9·30... | Souterhouse (No. 1 Pit) ... | Scotland, West ... | 1 |
| ,, 17, 11·0 ... | Kenmuirhill ... ... | Do. ... ... | 1 |
| ,, 23, 3·0 ... | Devon ... ... ... | Scotland, East ... | 2 |
| ,, 27, 12·0 ... | Hamilton Palace (No. 1 Pit) | Scotland, West ... | 4 |
| Oct. 3, 7·0 ... | Carsehead (No. 2 Pit) ... | Do. ... | 1 |
| ,, 4, 11·0 ... | Haugh (No. 2 Pit) ... | Do. ... | 1 |
| ,, 8, 10·30... | Barglachan (No. 2 Pit) ... | Do. ... | 1 |
| ,, 16, 6·0 ... | Gartness ... ... ... | Scotland, East ... | 2 |
| ,, 21, 6·30... | Bowhill ... ... ... | Do. ... | 1 |
| ,, 22, 14·0 ... | Penygraig ... ... ... | Cardiff ... ... ... | 1 |
| ,, 24, 8·0 ... | Roman Camp (Oil-shale) ... | Scotland, East ... | 1 |
| ,, 24, 18·0 ... | Blaen-cae-Gurwen ... | Swansea ... ... | 3 |
| ,, 28, 19·30... | Hulton ... ... ... | Manchester ... ... | 1 |
| ,, 31, 12·30... | Bentley ... ... ... | Staffordshire, South ... | 1 |
| Nov. 2, 5·0 ... | Caergynydd ... ... | Swansea ... ... | 1 |
| ,, 2, 7·0 ... | Kelty ... ... ... | Scotland, East ... | 1 |
| ,, 12, 15·0 ... | Bridgeness ... ... ... | Do. ... ... | 2 |
| ,, 14, 14·0 ... | Brownhill ... ... ... | Do. ... ... | 1 |
| ,, 23, 9·30... | New Cwmgorse ... ... | Swansea ... ... | 1 |
| ,, 23, 22·0 ... | Bradley ... ... ... | Staffordshire, South ... | 1 |
| ,, 25, 6·0 ... | Grange ... ... ... | Staffordshire, North ... | 1 |
| ,, 27, 11·30... | Wester Queenslie ... ... | Scotland, West ... | 1 |
| ,, 27, 15·0 ... | Duffryn Rhondda ... ... | Swansea ... ... | 1 |
| Dec. 5, 18·30... | Barrington ... ... ... | Newcastle-upon-Tyne | 2 |
| ,, 6, 0·45... | Shirebrook ... ... ... | Midland ... ... | 1 |
| ,, 6, 14·0 ... | Walkinshaw (No. 2 Pit) ... | Scotland, West ... | 2 |
| ,, 6, 18·0 ... | Addison Pit... ... ... | Newcastle-upon-Tyne | 2 |
| ,, 9, 8·0 ... | North Motherwell ... ... | Scotland, East ... | 2 |
| ,, 10, 23·30... | Cotes Park ... ... ... | Midland ... ... | 3 |
| ,, 11, 13·30... | Pumpherston (Oil-shale) ... | Scotland, East ... | 1 |
| ,, 12, 10·0 ... | Velinfran ... ... ... | Swansea ... ... | 1 |
| ,, 13, 7·30... | Bourtreehill (Capringstone, No. 6 Pit) ... ... | Scotland, West ... | 1 |
| ,, 20, 0·40... | Bridgeness ... ... ... | Scotland, East ... | 2 |
| ,, 30, 8·0 ... | Shirebrook ... ... ... | Midland ... ... | 2 |
| | | | 167 |

## TABLE IV.—BAROMETER, THERMOMETER, ETC., READINGS, 1901.

### JANUARY, 1901.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BAROMETER. | | | | TEMPERATURE. | | | | BAROMETER. | | | | TEMPERATURE. | | |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. |
| 1 | 29·988 | 30·001 | 30·002 | 30·105 | 40·1 | 37·1 | S | 1 | 29·662 | 29·787 | 29·830 | 29·906 | 43·1 | 38·9 | WSW |
| 2 | 30·145 | 30·218 | 30·238 | 30·272 | 43·4 | 32·6 | WSW | 2 | 29·911 | 29·990 | 30·099 | 30·187 | 44·7 | 38·3 | W |
| 3 | 30·294 | 30·352 | 30·366 | 30·400 | 40·1 | 32·9 | NNW | 3 | 30·221 | 30·252 | 30·251 | 30·258 | 45·1 | 38·4 | SSW |
| 4 | 30·399 | 30·439 | 30·398 | 30·407 | 39·4 | 30·6 | NE | 4 | 30·261 | 30·274 | 30·268 | 30·276 | 45·3 | 43·6 | WSW |
| 5 | 30·427 | 30·457 | 30·392 | 30·328 | 37·2 | 27·0 | NE | 5 | 30·269 | 30·307 | 30·307 | 30·311 | 44·1 | 34·3 | S |
| 6 | 30·231 | 30·181 | 30·125 | 30·167 | 33·0 | 27·9 | ENE | 6 | 30·328 | 30·368 | 30·307 | 30·293 | 36·1 | 31·3 | E |
| 7 | 30·136 | 30·096 | 30·038 | 30·019 | 30·3 | 26·9 | E | 7 | 30·234 | 30·191 | 30·143 | 30·086 | 36·8 | 34·6 | E |
| 8 | 29·956 | 29·877 | 29·864 | 29·814 | 33·1 | 26·4 | E | 8 | 29·995 | 29·942 | 29·843 | 29·788 | 37·3 | 34·1 | E |
| 9 | 29·847 | 29·828 | 29·774 | 29·804 | 41·7 | 19·0 | E | 9 | 29·736 | 29·800 | 29·837 | 29·856 | 35·1 | 30·9 | NW |
| 10 | 29·833 | 29·907 | 29·917 | 29·969 | 49·7 | 39·1 | SE | 10 | 29·786 | 29·768 | 29·812 | 29·880 | 39·4 | 30·9 | E |
| 11 | 29·967 | 30·042 | 30·087 | 30·178 | 45·6 | 37·9 | ESE | 11 | 29·929 | 30·021 | 30·043 | 30·114 | 42·2 | 37·9 | E |
| 12 | 30·234 | 30·320 | 30·343 | 30·378 | 42·1 | 37·4 | ESE | 12 | 30·150 | 30·226 | 30·255 | 30·276 | 43·5 | 36·8 | ESE |
| 13 | 30·397 | 30·443 | 30·455 | 30·462 | 44·5 | 37·6 | SE | 13 | 30·257 | 30·245 | 30·197 | 30·225 | 43·6 | 34·9 | ESE |
| 14 | 30·455 | 30·436 | 30·352 | 30·356 | 45·4 | 31·0 | SE | 14 | 30·215 | 30·230 | 30·168 | 30·176 | 46·6 | 38·6 | NE |
| 15 | 30·281 | 30·220 | 30·069 | 29·981 | 40·1 | 30·6 | E | 15 | 30·138 | 30·098 | 29·994 | 29·886 | 40· | 33·1 | NE |
| 16 | 29·874 | 29·829 | 29·825 | 29·921 | 47·2 | 31·5 | SSE | 16 | 29·757 | 29·686 | 29·548 | 29·565 | 42·0 | 33·3 | NE |
| 17 | 29·972 | 30·063 | 30·068 | 30·103 | 48·4 | 39·4 | S | 17 | 29·654 | 29·816 | 29·868 | 29·906 | 45·9 | 39·9 | SW |
| 18 | 30·087 | 30·099 | 30·055 | 30·022 | 48·3 | 37·3 | S | 18 | 29·857 | 29·813 | 29·694 | 29·687 | 45·9 | 40·1 | S |
| 19 | 29·861 | 29·644 | 29·415 | 29·529 | 48·2 | 42·7 | S | 19 | 29·610 | 29·512 | 29·454 | 29·504 | 40·5 | 36·9 | NNE |
| 20 | 29·802 | 29·996 | 30·019 | 30·038 | 50·6 | 38·6 | W | 20 | 29·533 | 29·637 | 29·527 | 29·752 | 48·8 | 36·1 | WSW |
| 21 | 30·130 | 30·258 | 30·229 | 30·242 | 52·8 | 47·9 | SW | 21 | 29·915 | 29·898 | 29·826 | 29·844 | 50 | 41·3 | WSW |
| 22 | 30·223 | 30·226 | 30·210 | 30·342 | 50·3 | 47·8 | SW | 22 | 29·796 | 29·756 | 29·933 | 30·186 | 49·5 | 38·3 | NW |
| 23 | 30·521 | 30·606 | 30·526 | 30·456 | 47·9 | 33·2 | N | 23 | 30·298 | 30·394 | 30·371 | 30·297 | 43·0 | 38·3 | WSW |
| 24 | 30·306 | 30·177 | 30·053 | 29·986 | 47·0 | 40·0 | SSW | 24 | 30·127 | 29·916 | 29·633 | 29·515 | 44·2 | 36·3 | SW |
| 25 | 30·074 | 30·143 | 30·007 | 29·918 | 47·3 | 37·8 | SW | 25 | 29·560 | 29·478 | 29·447 | 29·432 | 39·1 | 32·4 | WNW |
| 26 | 29·881 | 29·928 | 29·814 | 29·666 | 49·8 | 38·1 | W | 26 | 29·464 | 29·574 | 29·365 | 29·191 | 40·3 | 31·7 | W |
| 27 | 29·505 | 29·348 | 29·236 | 29·423 | 54·5 | 38·0 | W | 27 | 28·981 | 28·952 | 28·908 | 29·107 | 48·1 | 32·9 | NW |
| 28 | 29·558 | 29·511 | 29·384 | 29·384 | 40·2 | 34·7 | W | 28 | 29·168 | 29·152 | 29·352 | 29·349 | 35·3 | 27·9 | NE |
| 29 | 29·501 | 29·455 | 29·470 | 29·509 | 38·7 | 31·2 | W | 29 | 29·309 | 29·461 | 29·441 | 29·362 | 37·1 | 27·6 | W |
| 30 | 29·417 | 29·380 | 29·338 | 29·379 | 40·1 | 31·0 | W | 30 | 29·292 | 29·366 | 29·343 | 29·377 | 37·9 | 32·1 | WNW |
| 31 | 29·370 | 29·426 | 29·480 | 29·578 | 36·7 | 30·1 | W | 31 | 29·386 | 29·466 | 29·535 | 29·615 | 39·4 | 33·9 | N |

### FEBRUARY, 1901.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·670 | 29·780 | 29·716 | 29·639 | 39·3 | 30·4 | W | 1 | 29·649 | 29·650 | 29·460 | 29·215 | 38·4 | 32·1 | WSW |
| 2 | 29·497 | 29·472 | 29·508 | 29·586 | 42·9 | 31·0 | S | 2 | 29·342 | 29·521 | 29·617 | 29·643 | 41·8 | 35·8 | NE |
| 3 | 29·573 | 29·579 | 29·544 | 29·567 | 39·0 | 32·8 | E | 3 | 29·587 | 29·577 | 29·565 | 29·580 | 40·0 | 33·1 | W |
| 4 | 29·541 | 29·509 | 29·347 | 29·189 | 37·1 | 26·7 | NE | 4 | 29·468 | 29·314 | 29·331 | 29·415 | 35·1 | 30·1 | NE |
| 5 | 29·164 | 29·348 | 29·441 | 29·617 | 35 | 32·6 | N | 5 | 29·506 | 29·619 | 29·763 | 29·907 | 38·1 | 32·1 | N |
| 6 | 29·735 | 29·910 | 30·042 | 30·167 | 38·0 | 32·1 | N | 6 | 30·014 | 30·123 | 30·167 | 30·197 | 37·1 | 28·2 | NW |
| 7 | 30·213 | 30·273 | 30·249 | 30·271 | 38·2 | 30·8 | W | 7 | 30·152 | 30·097 | 30·112 | 30·168 | 44·0 | 32·2 | WSW |
| 8 | 30·274 | 30·327 | 30·326 | 30·361 | 40·1 | 31·3 | SW | 8 | 30·191 | 30·232 | 30·222 | 30·251 | 43·0 | 36·1 | W |
| 9 | 30·354 | 30·364 | 30·341 | 30·387 | 41·0 | 35·9 | W | 9 | 30·253 | 30·256 | 30·296 | 30·389 | 45·6 | 35·3 | W |
| 10 | 30·430 | 30·499 | 30·485 | 30·428 | 42·1 | 36·5 | N | 10 | 30·454 | 30·481 | 30·421 | 30·373 | 43·9 | 35·1 | W |
| 11 | 30·309 | 30·320 | 30·298 | 30·316 | 38·5 | 29·1 | NE | 11 | 30·391 | 30·431 | 30·397 | 30·369 | 39·1 | 28·9 | NNE |
| 12 | 30·270 | 30·253 | 30·200 | 30·226 | 37·9 | 27·0 | NW | 12 | 30·329 | 30·310 | 30·269 | 30·219 | 38·9 | 26·9 | W |
| 13 | 30·201 | 30·232 | 30·337 | 30·463 | 36·6 | 26·9 | NNE | 13 | 30·212 | 30·291 | 30·368 | 30·441 | 37·3 | 31·6 | E |
| 14 | 30·510 | 30·501 | 30·428 | 30·428 | 33·9 | 21·5 | N | 14 | 30·489 | 30·520 | 30·496 | 30·526 | 38·1 | 25·3 | WNW |
| 15 | 30·446 | 30·538 | 30·562 | 30·587 | 34·7 | 27·0 | NE | 15 | 30·548 | 30·574 | 30·523 | 30·489 | 39·8 | 25·9 | WNW |
| 16 | 30·506 | 30·417 | 30·306 | 30·239 | 43·2 | 28·9 | NW | 16 | 30·439 | 30·409 | 30·343 | 30·335 | 45·4 | 34·2 | WNW |
| 17 | 30·175 | 30·181 | 30·205 | 30·313 | 40·1 | 32·1 | N | 17 | 30·344 | 30·366 | 30·388 | 30·410 | 41·2 | 38·6 | N |
| 18 | 30·354 | 30·367 | 30·375 | 30·356 | 36·3 | 30·9 | NE | 18 | 30·397 | 30·343 | 30·264 | 30·251 | 45·4 | 34·9 | W |
| 19 | 30·284 | 30·239 | 30·181 | 30·226 | 35·8 | 31·3 | W | 19 | 30·244 | 30·264 | 30·247 | 30·275 | 42·7 | 35·1 | ESE |
| 20 | 30·230 | 30·264 | 30·261 | 30·305 | 35·0 | 28·8 | ENE | 20 | 30·274 | 30·287 | 30·259 | 30·287 | 39·1 | 35·0 | W |
| 21 | 30·295 | 30·303 | 30·231 | 30·212 | 38·5 | 23·4 | W | 21 | 30·262 | 30·270 | 30·241 | 30·262 | 42·6 | 29·1 | WNW |
| 22 | 30·206 | 30·245 | 30·196 | 30·215 | 44·7 | 38·4 | N | 22 | 30·225 | 30·213 | 30·121 | 30·101 | 43·8 | 31·9 | W |
| 23 | 30·142 | 30·105 | 30·086 | 30·134 | 46·0 | 37·9 | W | 23 | 30·011 | 30·040 | 30·036 | 30·008 | 46·6 | 37·8 | WNW |
| 24 | 30·071 | 29·984 | 29·859 | 29·820 | 45·8 | 39·4 | W | 24 | 29·865 | 29·710 | 29·593 | 29·577 | 45·9 | 40·3 | W |
| 25 | 29·746 | 29·719 | 29·648 | 29·652 | 48·1 | 38·2 | SW | 25 | 29·545 | 29·470 | 29·365 | 29·341 | 45·3 | 35·8 | SW |
| 26 | 29·581 | 29·533 | 29·428 | 29·380 | 44·9 | 40·0 | S | 26 | 29·290 | 29·288 | 29·208 | 29·185 | 44·7 | 39·9 | ESE |
| 27 | 29·218 | 29·181 | 29·352 | 29·529 | 48·2 | 43·0 | W | 27 | 29·160 | 29·208 | 29·305 | 29·419 | 44·4 | 36·9 | NNW |
| 28 | 29·553 | 29·539 | 29·441 | 29·422 | 51·0 | 39·1 | SW | 28 | 29·411 | 29·401 | 29·320 | 29·211 | 40·3 | 34·2 | ENE |

## MARCH, 1901.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Barometer. | | | | Temperature. | | Direction of wind at noon. | | Barometer. | | | | Temperature. | | Direction of wind at noon |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | |
| 1 | 29·201 | 29·076 | 29·127 | 29·243 | 52·0 | 39·1 | SW | 1 | 28·997 | 28·808 | 28·778 | 28·855 | 48·1 | 37·4 | SE |
| 2 | 29·307 | 29·184 | 29·112 | 29·106 | 52·1 | 37·8 | SSW | 2 | 28·937 | 28·895 | 28·721 | 28·750 | 44·1 | 37·7 | E |
| 3 | 29·198 | 29·339 | 29·482 | 29·703 | 48·3 | 38·1 | WSW | 3 | 28·887 | 29·121 | 29·304 | 29·463 | 45·7 | 35·9 | SW |
| 4 | 29·797 | 29·784 | 29·788 | 29·830 | 53·7 | 36·0 | SW | 4 | 29·461 | 29·407 | 29·448 | 29·270 | 47·0 | 35·3 | W |
| 5 | 29·719 | 29·558 | 29·611 | 29·832 | 54·9 | 40·5 | SW | 5 | 28·967 | 29·082 | 29·162 | 29·208 | 49·1 | 33 9 | WSW |
| 6 | 29·740 | 29·450 | 29·343 | 29·355 | 47·2 | 40·7 | SW | 6 | 29·179 | 29·087 | 28·930 | 28·953 | 42·1 | 36·9 | SW |
| 7 | 29·289 | 29·240 | 29·182 | 29·274 | 48·2 | 37·1 | WNW | 7 | 28·973 | 28·902 | 29·342 | 29·721 | 46·4 | 38·4 | NE |
| 8 | 29·464 | 29·739 | 29·914 | 30·106 | 45·3 | 38·1 | NNE | 8 | 29·941 | 30·118 | 30·180 | 30·248 | 45·2 | 38·2 | NNE |
| 9 | 30·188 | 30·274 | 30·253 | 30·283 | 43·1 | 35·3 | NNE | 9 | 30·208 | 30·2?2 | 30·158 | 30·167 | 44·3 | 35·1 | W |
| 10 | 30·249 | 30·231 | 30·096 | 30·043 | 42·6 | 31·3 | E | 10 | 30·142 | 30·129 | 30·041 | 29·999 | 48·7 | 43·8 | W |
| 11 | 29·914 | 29·869 | 29·814 | 29·868 | 45·0 | 30·5 | N | 11 | 29·895 | 29·867 | 29·823 | 29·844 | 48·4 | 43·4 | SW |
| 12 | 29 895 | 29·986 | 29·986 | 30·049 | 53·5 | 36·7 | W | 12 | 29·845 | 29·293 | 29·893 | 29·953 | 51·1 | 42·8 | W |
| 13 | 30·070 | 30·076 | 29·981 | 29·980 | 42·2 | 31·8 | NE | 13 | 29·968 | 30·023 | 29·954 | 29·968 | 53·5 | 42·6 | SE |
| 14 | 29·930 | 29·912 | 29·859 | 29·861 | 46·0 | 37·2 | NE | 14 | 29·980 | 30·020 | 30 001 | 3.·002 | 47·4 | 37·4 | ESE |
| 15 | 29·785 | 29·749 | 29·702 | 29·707 | 42·2 | 37·9 | NE | 15 | 29·939 | 29·912 | 29·832 | 29 814 | 40·4 | 37·9 | ENE |
| 16 | 29·676 | 29·703 | 29·721 | 29·779 | 44·9 | 37·1 | N | 16 | 29·771 | 29·765 | 29·763 | 29·813 | 42·3 | 37·1 | ENE |
| 17 | 29·773 | 29·754 | 29·679 | 29·674 | 47·7 | 36·6 | ESE | 17 | 29·815 | 29 836 | 29·806 | 29·849 | 46·1 | 38·1 | E |
| 18 | 29·594 | 29·585 | 29·549 | 29·573 | 42·0 | 36·4 | NE | 18 | 29·832 | 29·811 | 29·795 | 29·838 | 42·8 | 32·9 | NE |
| 19 | 29·538 | 29·531 | 29·471 | 29·454 | 41·1 | 34·8 | NNE | 19 | 29·830 | 29·855 | 29·858 | 29·910 | 40·9 | 35·8 | NE |
| 20 | 29·479 | 29·534 | 29·530 | 29·623 | 41·3 | 37·0 | NE | 20 | 29·895 | 29·928 | 29·938 | 30·008 | 43·3 | 36·6 | ENE |
| 21 | 29·673 | 29·815 | 29·876 | 30·032 | 42·1 | 34·3 | NE | 21 | 30·049 | 30·138 | 30·164 | 30·250 | 43·3 | 35·5 | NE |
| 22 | 30·139 | 30·276 | 30·327 | 30·426 | 42·9 | 31·9 | NE | 22 | 30·299 | 30·396 | 30·404 | 30·471 | 43·7 | 35·4 | E |
| 23 | 30·439 | 30·470 | 30·415 | 30·418 | 42·6 | 35·1 | N | 23 | 30·475 | 30·493 | 30·428 | 30·417 | 45·3 | 34·2 | W |
| 24 | 30·339 | 30·301 | 30·146 | 30·034 | 44·2 | 33·1 | NE | 24 | 30·330 | 30·227 | 30·069 | 30·049 | 45·4 | 32·4 | W |
| 25 | 29·894 | 29·877 | 29·872 | 29·961 | 38·1 | 29·4 | NE | 25 | 30·081 | 30·099 | 30·061 | 30·091 | 37 3 | 26·0 | N |
| 26 | 29·975 | 29·980 | 29·888 | 29·854 | 37 7 | 27·0 | NW | 26 | 30·030 | 29·935 | 29·841 | 29·836 | 38·8 | 25·3 | NW |
| 27 | 29·756 | 29·711 | 29·642 | 29·669 | 38·4 | 27·2 | NW | 27 | 29·773 | 29·746 | 29·692 | 29·728 | 36·6 | 26·0 | NNW |
| 28 | 29·659 | 29·725 | 29·752 | 29·787 | 38·6 | 25·7 | N | 28 | 29·736 | 29·731 | 29·733 | 29·749 | 39·5 | 27·6 | N |
| 29 | 29·795 | 29·816 | 29·713 | 29·564 | 42·1 | 26·0 | SW | 29 | 29·633 | 29·577 | 29·333 | 29·140 | 38·5 | 24·5 | SE |
| 30 | 29·345 | 29·170 | 29·105 | 29·215 | 43·9 | 39·0 | SW | 30 | 28·898 | 28·774 | 28·725 | 28·783 | 36·7 | 29·1 | N |
| 31 | 29·190 | 29·200 | 29·181 | 29·278 | 51·3 | 40·6 | S | 31 | 28·798 | 28·840 | 28·917 | 28·918 | 43·1 | 35·5 | SW |

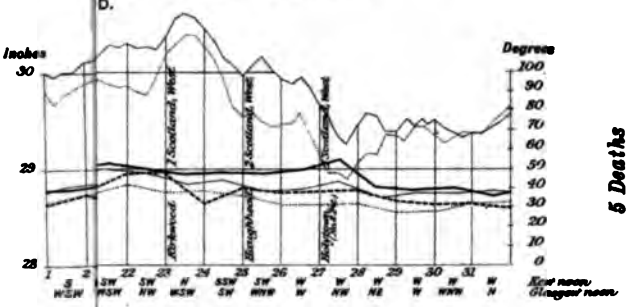
## APRIL, 1901.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·378 | 29·586 | 29·720 | 29·919 | 50·3 | 36·3 | WSW | 1 | 29·069 | 29·289 | 29·460 | 29·657 | 44·6 | 35·1 | WNW |
| 2 | 30·005 | 30·005 | 29·871 | 29·704 | 51·0 | 30·8 | S | 2 | 29·704 | 29·635 | 29·376 | 29·319 | 47·3 | 32·8 | SSE |
| 3 | 29·573 | 29·613 | 29·781 | 29·612 | 56·6 | 45·1 | WSW | 3 | 29·182 | 29·275 | 29·378 | 29·399 | 47·9 | 39·2 | WSW |
| 4 | 29·467 | 29·822 | 29·995 | 30·165 | 52·8 | 39·1 | WNW | 4 | 29·369 | 29·483 | 29·767 | 29·932 | 45·9 | 32·6 | WSW |
| 5 | 30·142 | 30·074 | 30·045 | 30·123 | 47·0 | 34·0 | E | 5 | 29·975 | 30·011 | 29·965 | 29·946 | 46·1 | 33·0 | WNW |
| 6 | 30·021 | 29·792 | 29·628 | 29·653 | 55·0 | 33·2 | S | 6 | 29·800 | 29·581 | 29·338 | 29·317 | 42·1 | 32·1 | E |
| 7 | 29·651 | 29·687 | 29·684 | 29·586 | 60·0 | 49·6 | SW | 7 | 29·362 | 29·416 | 29·370 | 29·183 | 53·5 | 40·9 | SW |
| 8 | 29·516 | 29·590 | 29·595 | 29·478 | 56·2 | 45·9 | SW | 8 | 28·974 | 28·911 | 29·078 | 29·160 | 47·3 | 38·1 | SW |
| 9 | 29·574 | 29·686 | 29·634 | 29·590 | 55·2 | 43·6 | SW | 9 | 29·227 | 29·350 | 29·383 | 29·363 | 48·9 | 40 3 | W |
| 10 | 29·495 | 29·398 | 29·432 | 29·544 | 52·0 | 39·2 | SSW | 10 | 29·293 | 29·278 | 29·287 | 29·389 | 47·6 | 40·4 | WSW |
| 11 | 29·512 | 29·414 | 29·379 | 29·511 | 52·2 | 42·4 | SW | 11 | 29·442 | 29·492 | 29·515 | 29·666 | 50·1 | 31·9 | NNW |
| 12 | 29·638 | 29·783 | 29·877 | 29·993 | 48·1 | 37·1 | N | 12 | 29·763 | 29·893 | 29·897 | 29·875 | 46·9 | 36·2 | NW |
| 13 | 29·972 | 29·913 | 29·738 | 29·840 | 49·3 | 36·9 | SW | 13 | 29·698 | 29·529 | 29·629 | 29·648 | 49·1 | 35·3 | NW |
| 14 | 29·782 | 29·551 | 29·417 | 29·458 | 56·6 | 38·8 | S | 14 | 29·493 | 29·270 | 29·141 | 29·131 | 48·6 | 37·2 | WSW |
| 15 | 29·381 | 29·459 | 29·421 | 29·470 | 49·1 | 38·0 | W | 15 | 29·132 | 29·164 | 29·174 | 29·185 | 41·7 | 34·6 | W |
| 16 | 29·434 | 29·469 | 29·652 | 29·854 | 49·9 | 37·9 | NW | 16 | 29·311 | 29·532 | 29·730 | 29·921 | 50·1 | 34·3 | NE |
| 17 | 30·017 | 30·196 | 30·216 | 30·254 | 53·2 | 36·0 | NNW | 17 | 30·014 | 30·079 | 30·075 | 30·077 | 52·7 | 34·0 | W |
| 18 | 30·267 | 30·269 | 30·211 | 30·225 | 58·1 | 40·2 | W | 18 | 30·019 | 30·001 | 29·993 | 29·990 | 49·5 | 44·3 | SW |
| 19 | 30·211 | 30·194 | 30·103 | 30·067 | 61·0 | 34·9 | S | 19 | 29·958 | 29·919 | 29·894 | 29·915 | 59·1 | 41·9 | SW |
| 20 | 30·035 | 30·005 | 29·939 | 29·939 | 66·9 | 43·0 | SE | 20 | 29·914 | 29·904 | 29·833 | 29·951 | 64·1 | 41·9 | S |
| 21 | 29·894 | 29·894 | 29·845 | 29·834 | 69·6 | 47·6 | SE | 21 | 29·823 | 29·826 | 29·753 | 29·763 | 69·4 | 46·0 | SW |
| 22 | 29·808 | 29·816 | 29·815 | 29·849 | 68·3 | 44·9 | S | 22 | 29·702 | 29·699 | 29·698 | 29·723 | 63·9 | 48·3 | SW |
| 23 | 29·847 | 29·882 | 29·884 | 29·958 | 73·0 | 46·0 | SW | 23 | 29·722 | 29·760 | 29·886 | 30·015 | 59·7 | 45·8 | WSW |
| 24 | 29·970 | 29·967 | 29·944 | 29·944 | 67·3 | 46·9 | E | 24 | 30·060 | 30·045 | 29·938 | 29·976 | 62·1 | 37·9 | E |
| 25 | 29·886 | 29·889 | 29·849 | 29·873 | 63·8 | 48·5 | ENE | 25 | 29·988 | 30·001 | 29·974 | 30·042 | 61·1 | 41·8 | NE |
| 26 | 29·873 | 29·915 | 29·852 | 29·889 | 55·1 | 40·3 | NE | 26 | 30·104 | 30·125 | 30·066 | 30·114 | 59·8 | 40·9 | ENE |
| 27 | 29·838 | 29·849 | 29·850 | 29·921 | 51·2 | 37 0 | N | 27 | 30·087 | 30·080 | 30·042 | 30·047 | 50·4 | 38·8 | ENE |
| 28 | 29·908 | 29·934 | 29·902 | 29·922 | 53·2 | 32·3 | WSW | 28 | 29·999 | 29·982 | 29·934 | 29·946 | 49·3 | 40·9 | ESE |
| 29 | 29·887 | 29·868 | 29·812 | 29·883 | 57·2 | 31·9 | N | 29 | 29·921 | 29·909 | 29·835 | 29·845 | 59·1 | 44 8 | ENE |
| 30 | 29·919 | 29·966 | 29·948 | 30·034 | 61·1 | 39·9 | N | 30 | 29·821 | 29·887 | 29·945 | 30·039 | 55·4 | 44·3 | ESE |

DIA TEMPERATURES AND THE DIRECTION
THER WITH THE EXPLOSIONS
D.

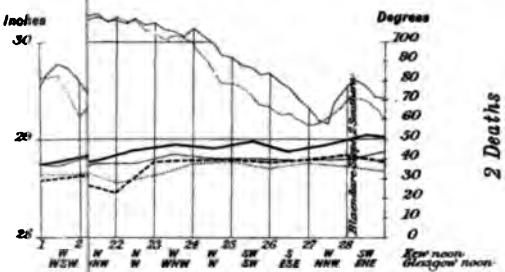
1901.

JANUARY.



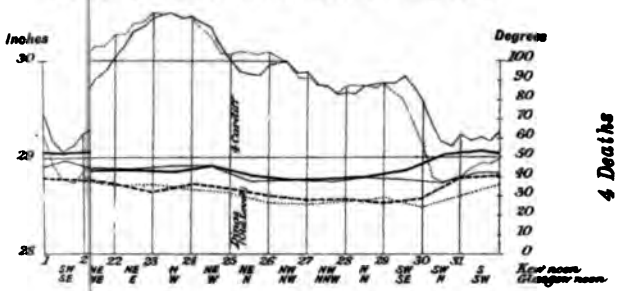

5 Deaths

FEBRUARY.

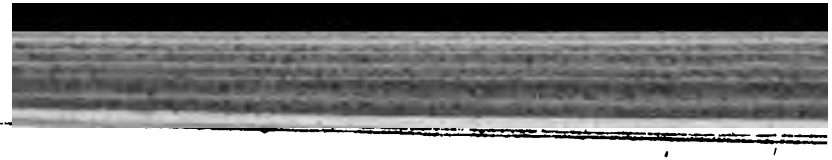



2 Deaths

MARCH.




4 Deaths



## MAY, 1901.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BAROMETER. | | | | TEMPERATURE. | | | | BAROMETER. | | | | TEMPERATURE. | | |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. |
| 1 | 30·056 | 30·063 | 30·072 | 30·117 | 61·3 | 35·7 | E | 1 | 30·115 | 30·204 | 30·175 | 30·230 | 60·7 | 42·3 | E |
| 2 | 30·117 | 30·183 | 30·206 | 30·272 | 57·0 | 46·4 | N | 2 | 30·253 | 30·279 | 30·368 | 30·362 | 64·8 | 41·3 | E |
| 3 | 30·293 | 30·333 | 30·280 | 30·324 | 66·1 | 45·6 | NE | 3 | 30·382 | 30·402 | 30·365 | 30·379 | 66·1 | 41·5 | NE |
| 4 | 30·310 | 30·323 | 30·238 | 30·218 | 57·5 | 40·5 | N | 4 | 30·358 | 30·322 | 30·212 | 30·162 | 67·9 | 39·9 | NW |
| 5 | 30·122 | 30·035 | 29·855 | 29·763 | 60·0 | 40·5 | S | 5 | 30·047 | 29·914 | 29·800 | 29·723 | 56·5 | 44·1 | WNW |
| 6 | 29·612 | 29·583 | 29·459 | 29·388 | 52·9 | 41·7 | WNW | 6 | 29·598 | 29·456 | 29·279 | 29·210 | 53·7 | 38·0 | SW |
| 7 | 29·295 | 29·221 | 29·264 | 29·284 | 53·7 | 42·1 | SW | 7 | 29·125 | 29·153 | 29·216 | 29·307 | 46·5 | 41·9 | E |
| 8 | 29·293 | 29·390 | 29·499 | 29·618 | 52·7 | 41·2 | E | 8 | 29·400 | 29·544 | 29·693 | 29·854 | 55·7 | 41·3 | ENE |
| 9 | 29·674 | 29·763 | 29·839 | 29·907 | 54·3 | 41·2 | N | 9 | 29·903 | 29·940 | 29·960 | 29·990 | 50·8 | 45·0 | E |
| 10 | 29·938 | 30·010 | 30·036 | 30·062 | 53·3 | 41·9 | NW | 10 | 29·983 | 29·979 | 29·934 | 29·937 | 52·1 | 44·1 | SW |
| 11 | 30·102 | 30·155 | 30·202 | 30·280 | 59·2 | 38·2 | WNW | 11 | 30·006 | 30·112 | 30·190 | 30·291 | 57·1 | 41·5 | WNW |
| 12 | 30·339 | 30·385 | 30·342 | 30·406 | 61·0 | 39·9 | NNE | 12 | 30·322 | 30·361 | 30·350 | 30·382 | 63·1 | 37·2 | SW |
| 13 | 30·379 | 30·350 | 30·294 | 30·334 | 62·4 | 45·0 | NE | 13 | 30·394 | 30·396 | 30·342 | 30·370 | 66·1 | 44·5 | NW |
| 14 | 30·334 | 30·343 | 30·289 | 30·337 | 68·0 | 42·0 | N | 14 | 30·385 | 30·371 | 30·323 | 30·386 | 71·8 | 43·8 | E |
| 15 | 30·341 | 30·316 | 30·233 | 30·253 | 67·0 | 41·9 | NE | 15 | 30·412 | 30·396 | 30·311 | 30·328 | 65·5 | 46·2 | ENE |
| 16 | 30·204 | 30·190 | 30·137 | 30·158 | 57·9 | 43·6 | N | 16 | 30·274 | 30·215 | 30·123 | 30·158 | 69·6 | 43·2 | WSW |
| 17 | 30·155 | 30·206 | 30·191 | 30·222 | 54·2 | 40·5 | NE | 17 | 30·175 | 30·195 | 30·147 | 30·153 | 59·3 | 46·1 | ENE |
| 18 | 30·214 | 30·244 | 30·173 | 30·182 | 63·8 | 37·7 | N | 18 | 30·111 | 30·114 | 30·102 | 30·107 | 57·4 | 41·6 | W |
| 19 | 30·148 | 30·151 | 30·128 | 30·182 | 67·3 | 44·8 | NW | 19 | 30·093 | 30·109 | 30·098 | 30·169 | 64·8 | 49·0 | WSW |
| 20 | 30·221 | 30·277 | 30·262 | 30·335 | 65·1 | 45·0 | NE | 20 | 30·189 | 30·226 | 30·225 | 30·254 | 64·7 | 44·1 | W |
| 21 | 30·342 | 30·360 | 30·303 | 30·313 | 65·0 | 45·6 | ENE | 21 | 30·309 | 30·328 | 30·304 | 30·331 | 70·4 | 45·4 | W |
| 22 | 30·286 | 30·295 | 30·269 | 30·299 | 65·0 | 46·7 | NE | 22 | 30·383 | 30·409 | 30·386 | 30·473 | 69·3 | 46·7 | ENE |
| 23 | 30·311 | 30·322 | 30·308 | 30·347 | 64·1 | 45·3 | NE | 23 | 30·501 | 30·508 | 30·472 | 30·490 | 66·7 | 43·9 | NE |
| 24 | 30·321 | 30·291 | 30·218 | 30·221 | 67·2 | 45·1 | NE | 24 | 30·483 | 30·443 | 30·371 | 30·381 | 68·6 | 45·5 | ENE |
| 25 | 30·177 | 30·141 | 30·063 | 30·052 | 66·3 | 46·1 | N | 25 | 30·346 | 30·307 | 30·231 | 30·208 | 59·8 | 45·9 | E |
| 26 | 29·965 | 29·926 | 29·855 | 29·865 | 61·0 | 47·8 | N | 26 | 30·141 | 30·093 | 29·996 | 29·945 | 59·3 | 46·5 | E |
| 27 | 29·869 | 29·885 | 29·856 | 29·918 | 71·8 | 43·8 | SE | 27 | 29·870 | 29·846 | 29·810 | 29·805 | 52·1 | 47·6 | ENE |
| 28 | 29·921 | 29·941 | 29·885 | 29·874 | 75·9 | 47·1 | SW | 28 | 29·769 | 29·789 | 29·779 | 29·801 | 63·6 | 48·1 | WNW |
| 29 | 29·825 | 29·804 | 29·716 | 29·745 | 80·4 | 51·8 | S | 29 | 29·776 | 29·754 | 29·694 | 29·696 | 65·3 | 45·4 | S |
| 30 | 29·711 | 29·709 | 29·666 | 29·649 | 68·3 | 58·1 | S | 30 | 29·565 | 29·513 | 29·428 | 29·310 | 68·6 | 50·4 | S |
| 31 | 29·617 | 29·717 | 29·777 | 29·828 | 68·7 | 54·1 | SW | 31 | 29·300 | 29·364 | 29·390 | 29·422 | 64·1 | 51·0 | WSW |

## JUNE, 1901.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 29·837 | 29·850 | 29·814 | 29·829 | 69·3 | 48·3 | SW | 1 | 29·446 | 29·515 | 29·534 | 29·507 | 63·8 | 52·9 | SSW |
| 2 | 29·816 | 29·868 | 29·907 | 29·989 | 69·1 | 53·8 | SW | 2 | 29·464 | 29·520 | 29·588 | 29·753 | 61·7 | 53·4 | SW |
| 3 | 30·050 | 30·080 | 30·065 | 30·087 | 68·7 | 51·1 | SW | 3 | 29·832 | 29·912 | 29·932 | 29·960 | 64·4 | 50·4 | SW |
| 4 | 30·092 | 30·125 | 30·054 | 30·078 | 71·5 | 50·9 | WSW | 4 | 29·914 | 29·894 | 29·827 | 29·777 | 60·5 | 52·9 | SW |
| 5 | 30·090 | 30·116 | 30·063 | 30·090 | 72·9 | 50·5 | SW | 5 | 29·852 | 29·906 | 29·962 | 30·061 | 57·8 | 46·3 | SW |
| 6 | 30·102 | 30·197 | 30·212 | 30·189 | 69·2 | 54·3 | NNE | 6 | 30·131 | 30·234 | 30·265 | 30·309 | 61·7 | 48·0 | WNW |
| 7 | 30·297 | 30·288 | 30·209 | 30·203 | 68·0 | 46·8 | NE | 7 | 30·298 | 30·279 | 30·223 | 30·194 | 67·1 | 43·3 | W |
| 8 | 30·143 | 30·111 | 30·020 | 30·003 | 72·0 | 48·1 | E | 8 | 30·150 | 30·102 | 29·994 | 29·946 | 74·7 | 43·8 | W |
| 9 | 29·945 | 29·882 | 29·800 | 29·804 | 78·6 | 44·7 | SSW | 9 | 29·849 | 29·803 | 29·751 | 29·790 | 61·6 | 47·9 | W |
| 10 | 29·882 | 29·950 | 29·936 | 29·960 | 68·1 | 51·4 | WNW | 10 | 29·804 | 29·804 | 29·729 | 29·634 | 58·5 | 44·4 | WSW |
| 11 | 29·938 | 29·967 | 29·973 | 29·999 | 67·4 | 48·8 | WNW | 11 | 29·602 | 29·717 | 29·763 | 29·776 | 53·5 | 41·8 | WNW |
| 12 | 29·931 | 29·846 | 29·669 | 29·592 | 62·8 | 47·6 | W | 12 | 29·732 | 29·663 | 29·576 | 29·519 | 53·2 | 42·6 | NW |
| 13 | 29·593 | 29·599 | 29·578 | 29·548 | 56·7 | 43·1 | W | 13 | 29·351 | 29·328 | 29·369 | 29·503 | 60·3 | 42·4 | WNW |
| 14 | 29·548 | 29·651 | 29·741 | 29·853 | 63·0 | 49·1 | N | 14 | 29·644 | 29·739 | 29·792 | 29·896 | 63·2 | 46·3 | NE |
| 15 | 29·921 | 29·986 | 29·988 | 30·001 | 62·8 | 44·2 | N | 15 | 29·921 | 29·936 | 29·921 | 29·935 | 60·1 | 46·4 | W |
| 16 | 29·968 | 29·988 | 29·976 | 30·033 | 62·0 | 49·3 | WNW | 16 | 29·899 | 29·911 | 29·903 | 29·970 | 60·6 | 46·4 | W |
| 17 | 30·016 | 30·015 | 29·965 | 29·967 | 59·9 | 48·8 | W | 17 | 29·971 | 29·964 | 29·931 | 30·019 | 59·1 | 43·0 | NW |
| 18 | 29·940 | 29·995 | 30·060 | 30·141 | 61·1 | 45·7 | N | 18 | 30·078 | 30·090 | 30·067 | 30·086 | 62·4 | 43·9 | NNW |
| 19 | 30·176 | 30·194 | 30·166 | 30·162 | 68·3 | 40·2 | SSW | 19 | 30·047 | 29·989 | 29·904 | 29·865 | 55·5 | 47·0 | S |
| 20 | 30·103 | 30·105 | 30·078 | 30·075 | 64·4 | 51·6 | S | 20 | 29·863 | 29·844 | 29·758 | 29·757 | 61·8 | 51·6 | WSW |
| 21 | 30·080 | 30·045 | 29·988 | 29·995 | 76·8 | 59·5 | S | 21 | 29·720 | 29·799 | 29·830 | 29·836 | 66·4 | 52·9 | SW |
| 22 | 29·941 | 29·874 | 29·770 | 29·733 | 76·0 | 57·2 | ESE | 22 | 29·819 | 29·798 | 29·747 | 29·623 | 64·4 | 51·1 | SW |
| 23 | 29·706 | 29·762 | 29·879 | 30·020 | 68·3 | 53·0 | SW | 23 | 29·422 | 29·420 | 29·500 | 29·743 | 59·2 | 52·1 | W |
| 24 | 30·084 | 30·139 | 30·172 | 30·292 | 67·3 | 47·8 | W | 24 | 29·892 | 30·031 | 30·133 | 30·240 | 60·1 | 50·6 | WNW |
| 25 | 30·342 | 30·385 | 30·374 | 30·394 | 70·3 | 49·0 | N | 25 | 30·290 | 30·340 | 30·371 | 30·377 | 59·2 | 44·7 | WSW |
| 26 | 30·397 | 30·379 | 30·300 | 30·312 | 73·7 | 50·1 | N | 26 | 30·357 | 30·345 | 30·325 | 30·301 | 61·8 | 52·6 | WSW |
| 27 | 30·293 | 30·282 | 30·209 | 30·231 | 74·0 | 52·5 | E | 27 | 30·257 | 30·240 | 30·197 | 30·189 | 64·1 | 47·8 | W |
| 28 | 30·163 | 30·130 | 30·075 | 30·105 | 72·3 | 53·0 | E | 28 | 30·159 | 30·150 | 30·124 | 30·182 | 67·3 | 47·4 | N |
| 29 | 30·087 | 30·102 | 30·077 | 30·074 | 73·7 | 58·6 | E | 29 | 30·193 | 30·197 | 30·171 | 30·201 | 65·1 | 50·1 | ENE |
| 30 | 30·050 | 29·969 | 29·889 | 29·824 | 69·1 | 55·0 | ENE | 30 | 30·193 | 30·167 | 30·086 | 30·066 | 62·8 | 49·3 | ENE |

## JULY, 1901.

### KEW.

| Date. | Barometer. 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Temperature. Max | Min. | Direction of wind at noon. |
|---|---|---|---|---|---|---|---|
| 1 | 29·713 | 29·714 | 29·660 | 29·671 | 72·1 | 57·0 | SSW |
| 2 | 29·609 | 29·583 | 29·600 | 29·651 | 69·1 | 56·3 | E |
| 3 | 29·638 | 29·718 | 29·777 | 29·879 | 71·2 | 56·3 | E |
| 4 | 29·942 | 30·039 | 30·029 | 30·073 | 77·9 | 57·3 | N |
| 5 | 30·068 | 30·104 | 30·065 | 30·076 | 80·0 | 59·8 | W |
| 6 | 30·070 | 30·086 | 30·127 | 30·184 | 71·0 | 59·3 | NE |
| 7 | 30·203 | 30·236 | 30·211 | 30·226 | 68·2 | 54·7 | ENE |
| 8 | 30·222 | 30·194 | 30·099 | 30·106 | 75·4 | 48·4 | NE |
| 9 | 30·063 | 30·052 | 29·992 | 30·040 | 77·1 | 48·9 | E |
| 10 | 30·046 | 30·057 | 30·029 | 30·077 | 80·5 | 51·8 | N |
| 11 | 30·08' | 30·081 | 30·035 | 30·062 | 83·7 | 56·5 | E |
| 12 | 30·057 | 30·056 | 30·016 | 30·087 | 83·8 | 59·1 | W |
| 13 | 30·070 | 30·080 | 30·062 | 30·074 | 68·9 | 57·9 | N |
| 14 | 30·036 | 30·024 | 29·981 | 29·973 | 68·3 | 52·7 | NE |
| 15 | 29·965 | 30·009 | 30·030 | 30·100 | 76·5 | 54·2 | W |
| 16 | 30·138 | 30·166 | 30·136 | 30·193 | 81·0 | 52·9 | SW |
| 17 | 30·223 | 30·249 | 30·229 | 30·234 | 82·0 | 54·0 | WNW |
| 18 | 30·215 | 30·204 | 30·129 | 30·155 | 85·6 | 62·2 | ENE |
| 19 | 30·107 | 30·092 | 30·030 | 30·078 | 87·6 | 57·9 | E |
| 20 | 30·078 | 30·082 | 30·017 | 30·017 | 85·2 | 59·3 | E |
| 21 | 29·920 | 29·839 | 29·753 | 29·783 | 86·9 | 58·2 | S |
| 22 | 29·774 | 29·823 | 29·813 | 29·835 | 72·5 | 58·3 | W |
| 23 | 29·821 | 29·838 | 29·779 | 29·740 | 68·3 | 56·1 | SW |
| 24 | 29·636 | 29·537 | 29·454 | 29·521 | 70·3 | 55·3 | ESE |
| 25 | 29·515 | 29·542 | 29·575 | 29·603 | 70·1 | 56·3 | W |
| 26 | 29·605 | 29·632 | 29·636 | 29·670 | 63·2 | 56·1 | SW |
| 27 | 29·651 | 29·699 | 29·723 | 29·800 | 67·8 | 57·2 | SE |
| 28 | 29·800 | 29·825 | 29·823 | 29·897 | 70·3 | 52·0 | SE |
| 29 | 29·956 | 30·030 | 30·056 | 30·129 | 74·0 | 51·9 | NW |
| 30 | 30·165 | 30·198 | 30·178 | 30·229 | 80·1 | 54·1 | NW |
| 31 | 30·234 | 30·229 | 30·139 | 30·139 | 76·3 | 60·1 | N |

### GLASGOW.

| Date. | Barometer. 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Temperature. Max | Min. | Direction of wind at noon. |
|---|---|---|---|---|---|---|---|
| 1 | 29·988 | 29·919 | 29·853 | 29·849 | 62·6 | 51·6 | E |
| 2 | 29·798 | 29·823 | 29·814 | 29·855 | 60·6 | 50·8 | ESE |
| 3 | 29·857 | 29·895 | 29·884 | 29·934 | 72·8 | 50·6 | ENE |
| 4 | 29·947 | 29·969 | 29·967 | 29·998 | 76·9 | 50·6 | WSW |
| 5 | 30·004 | 30·042 | 30·058 | 30·094 | 65·6 | 57·0 | W |
| 6 | 30·118 | 30·169 | 30·178 | 30·202 | 63·8 | 53·8 | NE |
| 7 | 30·192 | 30·196 | 30·161 | 30·172 | 74·7 | 48·4 | W |
| 8 | 30·170 | 30·165 | 30·098 | 30·056 | 71·5 | 60·1 | W |
| 9 | 30·026 | 30·009 | 29·950 | 29·971 | 76·1 | 61·1 | SSE |
| 10 | 30·003 | 30·055 | 30·050 | 30·056 | 72·8 | 57·1 | W |
| 11 | 30·031 | 29·999 | 30·004 | 30·052 | 73·3 | 56·3 | WSW |
| 12 | 30·097 | 30·142 | 30·129 | 30·147 | 63·7 | 51·4 | NW |
| 13 | 30·138 | 30·135 | 30·113 | 30·117 | 67·3 | 53·3 | NW |
| 14 | 30·038 | 29·990 | 29·898 | 29·847 | 72·8 | 50·9 | SSW |
| 15 | 29·820 | 29·901 | 29·975 | 30·042 | 63·1 | 55·0 | W |
| 16 | 30·044 | 30·007 | 29·960 | 30·010 | 69·3 | 50·1 | SSW |
| 17 | 30·031 | 30·066 | 30·120 | 30·141 | 73·9 | 60·1 | SW |
| 18 | 30·124 | 30·134 | 30·092 | 30·080 | 75·6 | 63·6 | WSW |
| 19 | 30·049 | 30·060 | 30·043 | 30·072 | 75·6 | 59·6 | W |
| 20 | 30·080 | 30·065 | 29·944 | 29·916 | 75·1 | 59·1 | ENE |
| 21 | 29·858 | 29·823 | 29·738 | 29·733 | 67·7 | 59·8 | ENE |
| 22 | 29·732 | 29·787 | 29·763 | 29·769 | 73·7 | 57·3 | NW |
| 23 | 29·723 | 29·708 | 29·656 | 29·637 | 61·3 | 55·9 | W |
| 24 | 29·594 | 29·615 | 29·631 | 29·696 | 65·4 | 52·9 | ENE |
| 25 | 29·680 | 29·671 | 29·615 | 29·622 | 64·3 | 57·2 | NW |
| 26 | 29·659 | 29·728 | 29·744 | 29·797 | 71·4 | 56·7 | E |
| 27 | 29·806 | 29·851 | 29·849 | 29·894 | 71·1 | 59·1 | NE |
| 28 | 29·878 | 29·890 | 29·870 | 29·898 | 70·6 | 58·5 | E |
| 29 | 29·919 | 29·985 | 30·032 | 30·073 | 64·2 | 55·5 | SW |
| 30 | 30·082 | 30·116 | 30·150 | 30·201 | 67·8 | 56·9 | W |
| 31 | 30·220 | 30·216 | 30·165 | 30·134 | 69·6 | 53·3 | WSW |

## AUGUST, 1901.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 30·095 | 30·102 | 30·056 | 30·087 | 74·5 | 59·5 | N |
| 2 | 30·113 | 30·170 | 30·190 | 30·266 | 72·7 | 58·4 | NW |
| 3 | · | 30·274 | 30·175 | 30·136 | 72·7 | 56·1 | SW |
| 4 | · | 29·980 | 29·948 | 29·968 | 66·3 | 57·3 | SW |
| 5 | 30·003 | 30·053 | 30·030 | 30·007 | 65·9 | 53·1 | WNW |
| 6 | 29·887 | 29·770 | 29·719 | 29·852 | 72·2 | 53·8 | SW |
| 7 | 29·950 | 30·010 | 29·964 | 30·019 | 74·5 | 51·2 | SW |
| 8 | 30·010 | 30·030 | 30·020 | 30·042 | 76·6 | 61·3 | W |
| 9 | 30·022 | 29·996 | 29·882 | 29·827 | 81·8 | 54·6 | S |
| 10 | 29·678 | 29·599 | 29·631 | 29·818 | 80·6 | 58·0 | S |
| 11 | 29·890 | 29·918 | 29·917 | 29·922 | 70·4 | 51·1 | S |
| 12 | 29·866 | 29·853 | 29·881 | 29·947 | 66·4 | 53·0 | SSW |
| 13 | 29·996 | 30·041 | 30·045 | 30·092 | 70·9 | 54·2 | SW |
| 14 | 30·138 | 30·004 | 29·939 | 29·888 | 71·0 | 59·1 | SSW |
| 15 | 29·778 | 29·801 | 29·830 | 29·968 | 70·2 | 57·2 | NW |
| 16 | 30·033 | 30·113 | 30·142 | 30·187 | 69·1 | 53·9 | NW |
| 17 | 30·183 | 30·183 | 30·142 | 30·134 | 72·1 | 49·6 | S |
| 18 | 30·103 | 30·098 | 30·065 | 30·137 | 81·3 | 55·1 | ESE |
| 19 | 30·171 | 30·241 | 30·238 | 30·340 | 77·2 | 55·9 | NNE |
| 20 | 30·374 | 30·394 | 30·350 | 30·396 | 71·0 | 54·8 | NE |
| 21 | 30·389 | 30·388 | 30·323 | 30·346 | 73·5 | 53·3 | E |
| 22 | 30·328 | 30·358 | 30·282 | 30·286 | 74·9 | 18·9 | E |
| 23 | 30·263 | 30·249 | 30·170 | 30·178 | 76·1 | 48·2 | ENE |
| 24 | 30·150 | 30·148 | 30·060 | 30·051 | 76·8 | 49·7 | E |
| 25 | 29·950 | 29·835 | 29·655 | 29·558 | 82·0 | 53·1 | S |
| 26 | 29·413 | 29·423 | 29·435 | 29·637 | 63·0 | 50·9 | WSW |
| 27 | 29·729 | 29·789 | 29·775 | 29·695 | 61·6 | 48·3 | WSW |
| 28 | 29·753 | 29·864 | 29·899 | 29·969 | 61·1 | 46·4 | W |
| 29 | 29·987 | 30·050 | 30·070 | 30·080 | 65·5 | 49·9 | NW |
| 30 | 30·040 | 30·047 | 30·025 | 30·028 | 67·0 | 56·9 | SW |
| 31 | 29·995 | 30·002 | 29·968 | 29·994 | 67·0 | 56·0 | W |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 30·067 | 30·023 | 29·996 | 30·047 | 70·1 | 57·4 | SW |
| 2 | 30·120 | 30·163 | 30·174 | 30·214 | 63·7 | 51·8 | WNW |
| 3 | 30·176 | 30·126 | 29·946 | 29·800 | 65·9 | 53·4 | S |
| 4 | 29·664 | 29·670 | 29·707 | 29·815 | 60·7 | 53·0 | WSW |
| 5 | 29·827 | 29·878 | 29·871 | 29·802 | 58·4 | 50·8 | W |
| 6 | 29·645 | 29·595 | 29·685 | 29·796 | 63·2 | 50·8 | N |
| 7 | 29·778 | 29·704 | 29·729 | 29·723 | 62·3 | 54·6 | WSW |
| 8 | 29·687 | 29·801 | 29·846 | 29·835 | 62·3 | 55·9 | WSW |
| 9 | 29·810 | 29·783 | 29·734 | 29·707 | 69·3 | 58·4 | SSW |
| 10 | 29·668 | 29·627 | 29·523 | 29·510 | 63·0 | 57·3 | E |
| 11 | 29·546 | 29·688 | 29·739 | 29·780 | 63·4 | 52·8 | S |
| 12 | 29·770 | 29·734 | 29·694 | 29·734 | 65·1 | 51·6 | ESE |
| 13 | 29·772 | 29·818 | 29·835 | 29·808 | 66·1 | 51·3 | S |
| 14 | 29·742 | 29·736 | 29·700 | 29·693 | 62·4 | 56·3 | SSW |
| 15 | 29·670 | 29·723 | 29·779 | 29·855 | 65·3 | 55·3 | SW |
| 16 | 29·879 | 29·951 | 30·006 | 30·049 | 60·1 | 50·1 | WNW |
| 17 | 30·037 | 30·015 | 29·890 | 29·915 | 59·8 | 49·8 | SE |
| 18 | 29·947 | 30·011 | 30·120 | 30·207 | 64·1 | 54·7 | W |
| 19 | 30·289 | 30·366 | 30·367 | 30·394 | 64·6 | 44·3 | NNE |
| 20 | 30·407 | 30·425 | 30·376 | 30·384 | 69·0 | 46·5 | WNW |
| 21 | 30·371 | 30·349 | 30·288 | 30·288 | 70·2 | 46·4 | WSW |
| 22 | 30·265 | 30·273 | 30·276 | 30·280 | 70·6 | 49·3 | NNW |
| 23 | 30·268 | 30·266 | 30·214 | 30·210 | 64·8 | 54·7 | W |
| 24 | 30·163 | 30·129 | 30·007 | 29·941 | 69·1 | 53·1 | NE |
| 25 | 29·807 | 29·653 | 29·462 | 29·367 | 71·8 | 53·3 | SW |
| 26 | 29·301 | 29·376 | 29·464 | 29·527 | 58·2 | 50·1 | NNW |
| 27 | 29·525 | 29·569 | 29·591 | 29·641 | 58·5 | 47·7 | NW |
| 28 | 29·646 | 29·687 | 29·720 | 29·773 | 56·1 | 46·6 | NW |
| 29 | 29·785 | 29·839 | 29·800 | 29·722 | 60·9 | 47·5 | WSW |
| 30 | 29·659 | 29·710 | 29·818 | 29·891 | 64·5 | 51·9 | W |
| 31 | 29·926 | 29·993 | 29·984 | 30·023 | 60·6 | 46·9 | NW |

No observation.

## SEPTEMBER, 1901.

| KEW. | | | | | | | | GLASGOW. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BAROMETER. | | | | TEMPERATURE. | | | | BAROMETER. | | | | TEMPERATURE. | | |
| Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon. | Date. | 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Max | Min. | Direction of wind at noon |
| 1 | 30·014 | 30·071 | 30·041 | 30·116 | 64·0 | 52·8 | NE | 1 | 30·038 | 30·074 | 30·090 | 30·134 | 59·2 | 45·4 | N |
| 2 | 30·117 | 30·122 | 30·088 | 30·107 | 62·2 | 45·8 | E | 2 | 30·160 | 30·191 | 30·168 | 30·201 | 58·3 | 43·1 | NE |
| 3 | 30·063 | 30·060 | 30·004 | 30·001 | 63·9 | 53·6 | ENE | 3 | 30·197 | 30·220 | 30·191 | 30·193 | 54·2 | 46·2 | E |
| 4 | 29·952 | 29·966 | 29·934 | 29·945 | 63·4 | 50·6 | NE | 4 | 30·169 | 30·173 | 30·089 | 30·083 | 59·6 | 48·9 | E |
| 5 | 29·880 | 29·849 | 29·800 | 29·816 | 65·0 | 48·4 | ENE | 5 | 30·020 | 29·974 | 29·888 | 29·908 | 61·3 | 46·2 | ESE |
| 6 | 29·820 | 29·834 | 29·822 | 29·889 | 66·1 | 43·3 | ESE | 6 | 29·857 | 29·817 | 29·771 | 29·794 | 59·1 | 47·8 | SE |
| 7 | 29·880 | 29·920 | 29·885 | 29·894 | 70·2 | 46·9 | SE | 7 | 29·776 | 29·838 | 29·793 | 29 772 | 63·4 | 52·6 | ESE |
| 8 | 29·842 | 29·859 | 29·849 | 29·870 | 74·8 | 57·0 | SSW | 8 | 29·643 | 29·584 | 29·587 | 29·653 | 64·1 | 52·4 | SE |
| 9 | 29·851 | 29·894 | 29·876 | 29·904 | 69·7 | 54·2 | SSW | 9 | 29·670 | 29·720 | 29·738 | 29 767 | 64·4 | 57·2 | WSW |
| 10 | 29·919 | 29·966 | 29·949 | 30·004 | 68·7 | 55·0 | SW | 10 | 29·778 | 29·826 | 29·863 | 29·908 | 62·9 | 54·9 | SW |
| 11 | 30·023 | 30·017 | 29·970 | 29·989 | 60·7 | 51·3 | NW | 11 | 29·920 | 29·990 | 30·019 | 30·059 | 63·7 | 51·9 | WNW |
| 12 | 29·977 | 29·997 | 29·979 | 30·021 | 65·1 | 51·2 | NE | 12 | 30·045 | 30·015 | 29·973 | 30·003 | 64·0 | 49·5 | SW |
| 13 | 29·969 | 29·974 | 29·888 | 29·871 | 63·1 | 52·8 | N | 13 | 29·996 | 29·997 | 29·978 | 29·950 | 58·1 | 50·9 | ESE |
| 14 | 29·813 | 29·773 | 29·714 | 29·772 | 65·4 | 52·0 | ENE | 14 | 29·905 | 29·928 | 29·913 | 29·945 | 59·4 | 50·2 | NE |
| 15 | 29·776 | 29·803 | 29·792 | 29·824 | 62·8 | 46·0 | N | 15 | 29·933 | 29·932 | 29·846 | 29·832 | 58·9 | 46·4 | ESE |
| 16 | 29·801 | 29 787 | 29·688 | 29·608 | 64·0 | 40·6 | SSE | 16 | 29·757 | 29·696 | 29 577 | 29·516 | 58·3 | 45·3 | E |
| 17 | 29 494 | 29·393 | 29·349 | 29·596 | 65·0 | 57·0 | S | 17 | 29·377 | 29·277 | 29·221 | 29·450 | 60·5 | 49·4 | E |
| 18 | 29·851 | 30·038 | 30·041 | 30·057 | 63·1 | 48·4 | W | 18 | 29·627 | 29·750 | 29·763 | 29·711 | 58·3 | 47·5 | SW |
| 19 | 29·986 | 29·904 | 29·794 | 29 713 | 62·1 | 44·4 | SSW | 19 | 29·606 | 29·495 | 29·369 | 29·335 | 57 8 | 52·6 | SW |
| 20 | 29·522 | 29·471 | 29·480 | 29·480 | 68·3 | 56·7 | S | 20 | 29·190 | 29·034 | 29·126 | 29·249 | 61·7 | 54·2 | SSW |
| 21 | 29·435 | 29·434 | 29·444 | 29·521 | 65·5 | 54·3 | S | 21 | 29·287 | 29·325 | 29·306 | 29·334 | 60·5 | 50·9 | SE |
| 22 | 29·529 | 29·547 | 29·518 | 29·508 | 67·9 | 52·0 | SSE | 22 | 29·373 | 29·430 | 29·438 | 29 501 | 66·1 | 50·4 | SE |
| 23 | 29·461 | 29·505 | 29·599 | 29·691 | 65·9 | 55·0 | S | 23 | 29·514 | 29·550 | 29·550 | 29·587 | 62·0 | 53·4 | ENE |
| 24 | 29·735 | 29·830 | 29·832 | 29·870 | 68·0 | 51·3 | NW | 24 | 29·628 | 29·717 | 29·759 | 29·812 | 65·1 | 53·1 | S |
| 25 | 29·859 | 29·871 | 29·841 | 29 875 | 67·7 | 51·3 | SW | 25 | 29·780 | 29·782 | 29·735 | 29·727 | 64·4 | 50·4 | SE |
| 26 | 29·910 | 30·076 | 30·126 | 30·234 | 65·3 | 48·2 | N | 26 | 29·705 | 29·863 | 29·919 | 29·921 | 58·7 | 49·9 | WSW |
| 27 | 30·257 | 30·274 | 30·248 | 30·261 | 65·1 | 42·7 | SW | 27 | 29·820 | 29·788 | 29·785 | 29·789 | 61·1 | 52·1 | SW |
| 28 | 30·246 | 30·276 | 30·240 | 30·243 | 64·1 | 56·4 | SW | 28 | 29·767 | 29·860 | 29·864 | 29·891 | 64·7 | 60·1 | SSW |
| 29 | 30·219 | 30·227 | 30·130 | 30·139 | 70·6 | 50·3 | SSW | 29 | 29·926 | 29·975 | 29·998 | 30·063 | 61·7 | 51·7 | WSW |
| 30 | 30·126 | 30·138 | 30·078 | 30·079 | 63·8 | 47·9 | SSW | 30 | 30·097 | 30·148 | 30·087 | 30·056 | 55·8 | 45·8 | ESE |

## OCTOBER, 1901.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30·015 | 29·986 | 29·903 | 29·856 | 72·0 | 49·7 | S | 1 | 29·935 | 29·876 | 29·785 | 29·771 | 61·2 | 50·5 | E |
| 2 | 29·786 | 29·808 | 29·815 | 29·903 | 65·6 | 57·1 | E | 2 | 29·737 | 29·802 | 29·838 | 29·882 | 61·3 | 50·2 | W |
| 3 | 29·941 | 30·025 | 29·997 | 30·007 | 65·3 | 50·7 | W | 3 | 29·837 | 29·798 | 29·738 | 29·777 | 55·0 | 46·2 | SW |
| 4 | 29·931 | 29·947 | 29·988 | 30·039 | 57·2 | 47·3 | N | 4 | 29·833 | 29 930 | 29·952 | 29·912 | 54·8 | 44·3 | WNW |
| 5 | 30·006 | 29·914 | 29·729 | 29·678 | 57·1 | 41·2 | SW | 5 | 29·672 | 29·432 | 29·478 | 29·470 | 54·8 | 45·1 | WNW |
| 6 | 29·597 | 29·234 | 29·203 | 29·425 | 60·9 | 45·0 | W | 6 | 29·274 | 29·109 | 29·201 | 29·401 | 51·0 | 41·5 | NW |
| 7 | 29·566 | 29·629 | 29·649 | 29·704 | 52·7 | 40·9 | NW | 7 | 29·438 | 29·480 | 29·543 | 29·557 | 50·1 | 41·0 | NW |
| 8 | 29·694 | 29·655 | 29·524 | 29·459 | 59·2 | 42·6 | SW | 8 | 29·482 | 29·422 | 29·237 | 29·119 | 53·8 | 41·4 | W |
| 9 | 29·424 | 29·631 | 29·885 | 30·091 | 59·9 | 44·4 | NW | 9 | 29·231 | 29·651 | 29·891 | 30·012 | 53·1 | 41·4 | NNE |
| 10 | 30·149 | 30·204 | 30·147 | 30·162 | 58·2 | 40·9 | WSW | 10 | 29·980 | 29·918 | 29·908 | 29·999 | 53·3 | 38·3 | SW |
| 11 | 30·134 | 30·179 | 30·143 | 30·144 | 55·2 | 47·8 | N | 11 | 30·077 | 30·124 | 30·075 | 30·039 | 53·1 | 39·1 | NNE |
| 12 | 30·093 | 30·099 | 30·044 | 30·080 | 60·0 | 48·8 | E | 12 | 29·940 | 29·915 | 29·886 | 30·006 | 54·3 | 44·1 | S |
| 13 | 30·072 | 30·118 | 30·058 | 30·056 | 55·6 | 44·4 | ESE | 13 | 30·046 | 30·081 | 29·991 | 29·943 | 51·9 | 36·2 | SW |
| 14 | 29·978 | 29·936 | 29·851 | 29·849 | 58·3 | 42·9 | S | 14 | 29·832 | 29·796 | 29·740 | 29·741 | 54·8 | 41·1 | S |
| 15 | 29·802 | 29·796 | 29·731 | 29·715 | 55·2 | 44·3 | SE | 15 | 29·742 | 29·770 | 29·718 | 29·680 | 50·1 | 43·4 | W |
| 16 | 29·635 | 29·582 | 29·497 | 29·409 | 60·1 | 49·5 | E | 16 | 29·606 | 29·539 | 29·388 | 29·258 | 50· | 38·2 | ESE |
| 17 | 29·426 | 29·428 | 29·437 | 29·489 | 59·4 | 49·8 | SSW | 17 | 29·116 | 29·079 | 29·081 | 29·122 | 51·3 | 45·1 | SW |
| 18 | 29·448 | 29·362 | 29·297 | 29·452 | 58·3 | 44·4 | S | 18 | 29·110 | 29·015 | 29·043 | 29·135 | 49·5 | 45·0 | SSW |
| 19 | 29·536 | 29·641 | 29·695 | 29·772 | 57·0 | 38·0 | SW | 19 | 29 217 | 29·364 | 29·472 | 29·592 | 52·0 | 44·6 | SW |
| 20 | 29·811 | 29·866 | 29·827 | 29·807 | 55·6 | 33·8 | SW | 20 | 29·644 | 29·703 | 29·681 | 29·699 | 51 | 42·1 | WSW |
| 21 | 29·740 | 29·721 | 29·716 | 29·765 | 55·1 | 33·0 | SE | 21 | 29·688 | 29·724 | 29·742 | 29·780 | 46·3 | 36·3 | ENE |
| 22 | 29·778 | 29·810 | 29·824 | 29·893 | 51·1 | 39·0 | S | 22 | 29·793 | 29·810 | 29·788 | 29·816 | 47·3 | 39·4 | E |
| 23 | 29·936 | 30·039 | 30·065 | 30·152 | 52·3 | 40·7 | SSW | 23 | 29·838 | 29·911 | 29·943 | 29·982 | 49·6 | 40·6 | SW |
| 24 | 30·156 | 30·125 | 29·986 | 29·993 | 53·0 | 35·8 | S | 24 | 29·936 | 29·796 | 29·690 | 29 781 | 46·8 | 34·4 | ESE |
| 25 | 30·028 | 30·046 | 30·005 | 30·031 | 52·1 | 37·8 | SW | 25 | 29·819 | 29·856 | 29·834 | 29·896 | 48·7 | 40·9 | SW |
| 26 | 30·033 | 30·166 | 30·226 | 30·328 | 44·0 | 32·3 | W | 26 | 30·021 | 30·119 | 30·102 | 30·050 | 49·7 | 36·3 | WSW |
| 27 | 30·334 | 30·355 | 30·291 | 30·295 | 54·4 | 30·9 | SSW | 27 | 29·965 | 29·927 | 29·843 | 29·858 | 54·9 | 49·1 | SW |
| 28 | 30·219 | 30·168 | 30·067 | 30·019 | 58·5 | 46·0 | WSW | 28 | 29·781 | 29·695 | 29·632 | 29·634 | 59·1 | 54·8 | SW |
| 29 | 29·964 | 30·007 | 30·040 | 30·115 | 56·1 | 51·9 | SW | 29 | 29·760 | 30·034 | 30·238 | 30·365 | 55·3 | 41·3 | ENE |
| 30 | 30·163 | 30·217 | 30·196 | 30·206 | 55·1 | 48·2 | NE | 30 | 30·400 | 30·453 | 30·449 | 30·482 | 46·3 | 38·3 | ENE |
| 31 | 30·204 | 30 256 | 30·235 | 30·276 | 55·1 | 47·2 | ENE | 31 | 30·469 | 30·492 | 30·478 | 30·478 | 50·3 | 42·4 | E |

## NOVEMBER, 1901.

### KEW.

| Date. | Barometer. 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Temperature. Max | Min. | Direction of wind at noon. |
|---|---|---|---|---|---|---|---|
| 1 | 30·248 | 30·261 | 30·238 | 30·293 | 50·7 | 43·1 | E |
| 2 | 30·309 | 30·371 | 30·343 | 30·362 | 52·7 | 31·9 | E |
| 3 | 30·345 | 30·367 | 30·328 | 30·344 | 37·3 | 29·2 | E |
| 4 | 30·329 | 30·355 | 30·323 | 30·378 | 35·3 | 28·6 | E |
| 5 | 30·396 | 30·440 | 30·406 | 30·404 | 38·9 | 32·0 | E |
| 6 | 30·343 | 30·334 | 30·241 | 30·249 | 36·7 | 30·0 | SW |
| 7 | 30·248 | 30·274 | 30·242 | 30·252 | 46·7 | 32·1 | SW |
| 8 | 30·201 | 30·190 | 30·156 | 30·173 | 50·7 | 39·9 | NW |
| 9 | 30·155 | 30·177 | 30·146 | 30·152 | 49·7 | 41·7 | W |
| 10 | 30·094 | 30·074 | 29·992 | 29·940 | 51·9 | 45·9 | SW |
| 11 | 29·873 | 29·842 | 29·766 | 29·708 | 54·4 | 46·2 | WSW |
| 12 | 29·546 | 29·314 | 29·024 | 29·074 | 52·6 | 49·1 | S |
| 13 | 29·057 | 29·063 | 29·063 | 29·025 | 50·3 | 40·1 | W |
| 14 | 29·145 | 29·323 | 29·471 | 29·518 | 41·1 | 30·3 | NNW |
| 15 | 29·534 | 29·619 | 29·649 | 29·741 | 39·8 | 24·2 | W |
| 16 | 29·814 | 29·992 | 30·128 | 30·299 | 31·6 | 22·1 | W |
| 17 | 30·356 | 30·420 | 30·383 | 30·370 | 39·7 | 21·1 | W |
| 18 | 30·339 | 30·354 | 30·280 | 30·190 | 48·0 | 31·1 | W |
| 19 | 30·117 | 30·133 | 30·055 | 30·030 | 52·6 | 47·6 | W |
| 20 | 29·954 | 29·975 | 29·948 | 29·951 | 54·0 | 48·8 | W |
| 21 | 29·867 | 29·832 | 29·751 | 29·801 | 53·7 | 46·6 | WSW |
| 22 | 29·839 | 29·900 | 30·046 | 30·195 | 46·6 | 35·3 | W |
| 23 | 30·318 | 30·445 | 30·484 | 30·552 | 44·1 | 31·0 | NNE |
| 24 | 30·553 | 30·604 | 30·576 | 30·592 | 35·5 | 24·2 | NNE |
| 25 | 30·590 | 30·621 | 30·544 | 30·551 | 42·1 | 27·0 | NE |
| 26 | 30·509 | 30·505 | 30·427 | 30·412 | 44·4 | 32·6 | N |
| 27 | 30·382 | 30·410 | 30·368 | 30·337 | 46·0 | 30·3 | N |
| 28 | 30·256 | 30·313 | 30·372 | 30·465 | 46·2 | 37·1 | N |
| 29 | 30·483 | 30·507 | 30·462 | 30·459 | 42·9 | 31·0 | NW |
| 30 | 30·425 | 30·448 | 30·396 | 30·358 | 47·1 | 36·0 | W |

### GLASGOW.

| Date. | Barometer. 4 A.M. | 10 A.M. | 4 P.M. | 10 P.M. | Temperature. Max | Min. | Direction of wind at noon. |
|---|---|---|---|---|---|---|---|
| 1 | 30·421 | 30·406 | 30·329 | 30·326 | 50·6 | 40·0 | ENE |
| 2 | 30·313 | 30·326 | 30·291 | 30·330 | 49·4 | 37·8 | E |
| 3 | 30·298 | 30·301 | 30·261 | 30·267 | 49·8 | 40·5 | NE |
| 4 | 30·281 | 30·307 | 30·278 | 30·308 | 46·8 | 32·8 | W |
| 5 | 30·321 | 30·354 | 30·318 | 30·314 | 47·7 | 36·9 | NW |
| 6 | 30·242 | 30·234 | 30·142 | 30·166 | 51·3 | 42·0 | W |
| 7 | 30·154 | 30·181 | 30·139 | 30·122 | 50·1 | 43·2 | NW |
| 8 | 30·064 | 30·070 | 30·022 | 30·005 | 49·5 | 46·3 | W |
| 9 | 29·965 | 29·956 | 29·892 | 29·831 | 50·1 | 47·2 | WSW |
| 10 | 29·761 | 29·724 | 29·639 | 29·659 | 50·7 | 45·4 | W |
| 11 | 29·640 | 29·627 | 29·581 | 29·553 | 49·3 | 42·8 | WNW |
| 12 | 29·450 | 29·318 | 29·207 | 29·263 | 44·3 | 36·2 | NE |
| 13 | 29·391 | 29·482 | 29·486 | 29·490 | 40·8 | 33·5 | NE |
| 14 | 29·479 | 29·530 | 29·516 | 29·485 | 39·3 | 32·1 | N |
| 15 | 29·464 | 29·522 | 29·586 | 29·752 | 36·5 | 28·2 | NE |
| 16 | 29·846 | 29·952 | 30·028 | 30·084 | 38·0 | 22·2 | W |
| 17 | 30·081 | 30·092 | 30·057 | 30·036 | 47·1 | 36·7 | WSW |
| 18 | 30·034 | 29·956 | 29·762 | 29·652 | 51·3 | 45·1 | WSW |
| 19 | 29·611 | 29·560 | 29·472 | 29·607 | 52·9 | 45·9 | WSW |
| 20 | 29·662 | 29·700 | 29·687 | 29·600 | 46·3 | 38·3 | SE |
| 21 | 29·491 | 29·487 | 29·644 | 29·796 | 49·6 | 36·9 | W |
| 22 | 29·911 | 30·047 | 30·206 | 30·342 | 37·3 | 31·1 | ENE |
| 23 | 30·425 | 30·498 | 30·503 | 30·508 | 33·3 | 27·4 | ENE |
| 24 | 30·472 | 30·440 | 30·401 | 30·442 | 44·4 | 27·1 | SSW |
| 25 | 30·491 | 30·550 | 30·542 | 30·544 | 46·4 | 42·3 | WNW |
| 26 | 30·530 | 30·547 | 30·519 | 30·521 | 46·6 | 34·9 | WNW |
| 27 | 30·456 | 30·394 | 30·290 | 30·258 | 48·9 | 42·3 | W |
| 28 | 30·288 | 30·396 | 30·438 | 30·460 | 47·3 | 37·0 | W |
| 29 | 30·403 | 30·378 | 30·318 | 30·299 | 48·1 | 34·8 | WNW |
| 30 | 30·247 | 30·217 | 30·148 | 30·015 | 50·1 | 44·4 | W |

## DECEMBER, 1901.

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 30·289 | 30·288 | 30·303 | 30·308 | 48·8 | 39·2 | W | 1 | 30·008 | 30·081 | 30·058 | 29·984 | 50·0 | 47·3 | W |
| 2 | 30·272 | 30·274 | 30·229 | 30·236 | 52·0 | 43·4 | W | 2 | 29·904 | 29·965 | 29·971 | 30·011 | 50·3 | 44·9 | WNW |
| 3 | 30·219 | 30·242 | 30·245 | 30·323 | 47·4 | 35·9 | W | 3 | 30·076 | 30·174 | 30·201 | 30·240 | 46·1 | 40·1 | W |
| 4 | 30·349 | 30·407 | 30·362 | 30·334 | 40·4 | 30·7 | ENE | 4 | 30·219 | 30·197 | 30·101 | 30·019 | 47·1 | 39·8 | WSW |
| 5 | 30·250 | 30·168 | 30·054 | 30·003 | 44·4 | 25·4 | S | 5 | 29·868 | 29·717 | 29·683 | 29·769 | 46·9 | 39·4 | SW |
| 6 | 30·113 | 30·225 | 30·188 | 30·138 | 48·1 | 33·0 | W | 6 | 29·839 | 29·780 | 29·597 | 29·576 | 51·4 | 39·8 | SW |
| 7 | 30·030 | 29·993 | 29·996 | 29·928 | 55·3 | 48·1 | SW | 7 | 29·544 | 29·604 | 29·656 | 29·464 | 51·1 | 40·9 | W |
| 8 | 29·709 | 29·576 | 29·581 | 29·583 | 54·6 | 45·8 | WSW | 8 | 29·219 | 29·251 | 29·174 | 29·068 | 45·4 | 36·0 | WNW |
| 9 | 29·581 | 29·561 | 29·589 | 29·641 | 46·3 | 39·0 | W | 9 | 29·054 | 29·111 | 29·214 | 29·289 | 38·3 | 30·3 | NNW |
| 10 | 29·603 | 29·752 | 29·716 | 29·625 | 42·0 | 33·8 | W | 10 | 29·359 | 29·385 | 29·387 | 29·391 | 37·2 | 31·4 | W |
| 11 | 29·564 | 29·655 | 29·726 | 29·751 | 42·1 | 32·7 | WNW | 11 | 29·479 | 29·538 | 29·595 | 29·615 | 40·8 | 32·4 | W |
| 12 | 29·630 | 29·344 | 29·018 | 28·909 | 46·4 | 30·6 | SE | 12 | 29·591 | 29·576 | 29·506 | 29·497 | 34·4 | 23·6 | NW |
| 13 | 28·846 | 28·880 | 28·918 | 29·078 | 45·3 | 41·4 | NNE | 13 | 29·493 | 29·538 | 29·580 | 29·690 | 38·1 | 33·4 | NE |
| 14 | 29·143 | 29·307 | 29·409 | 29·595 | 42·1 | 36·7 | N | 14 | 29·751 | 29·829 | 29·900 | 29·946 | 37·4 | 33·8 | NNE |
| 15 | 29·739 | 29·848 | 29·789 | 29·684 | 36·6 | 32·3 | NNW | 15 | 29·694 | 29·786 | 29·563 | 29·392 | 36·1 | 30·2 | SW |
| 16 | 29·534 | 29·558 | 29·647 | 29·785 | 41·1 | 28·3 | SE | 16 | 29·422 | 29·576 | 29·631 | 29·683 | 36·9 | 28·3 | ENE |
| 17 | 29·812 | 29·818 | 29·657 | 29·472 | 40·7 | 23·2 | SE | 17 | 29·578 | 29·378 | 29·255 | 29·257 | 42·1 | 27·3 | WSW |
| 18 | 29·386 | 29·318 | 29·271 | 29·319 | 40·7 | 32·4 | WSW | 18 | 29·050 | 29·115 | 29·147 | 29·228 | 38·4 | 30·6 | NNW |
| 19 | 29·341 | 29·401 | 29·392 | 29·473 | 37·5 | 28·0 | WSW | 19 | 29·264 | 29·341 | 29·415 | 29·533 | 39·1 | 30·3 | NNW |
| 20 | 29·536 | 29·602 | 29·597 | 29·607 | 34·6 | 24·9 | N | 20 | 29·629 | 29·646 | 29·625 | 29·642 | 39·1 | 32·1 | NW |
| 21 | 29·595 | 29·601 | 29·553 | 29·489 | 34·5 | 28·7 | SW | 21 | 29·544 | 29·456 | 29·428 | 29·404 | 37·3 | 30·6 | S |
| 22 | 29·386 | 29·419 | 29·462 | 29·592 | 36·6 | 28·4 | E | 22 | 29·378 | 29·395 | 29·427 | 29·492 | 31·9 | 27·2 | WSW |
| 23 | 29·649 | 29·724 | 29·554 | 29·239 | 42·0 | 26·0 | SW | 23 | 29·466 | 29·326 | 29·052 | 28·784 | 36·4 | 28·5 | SE |
| 24 | 29·114 | 29·066 | 28·866 | 28·632 | 42·8 | 33·7 | SW | 24 | 28·619 | 28·640 | 28·612 | 28·585 | 38·4 | 33·4 | W |
| 25 | 28·761 | 28·792 | 28·858 | 28·946 | 40·2 | 31·3 | SW | 25 | 28·577 | 28·652 | 28·741 | 28·841 | 38·7 | 33·1 | NNE |
| 26 | 29·054 | 29·179 | 29·255 | 29·354 | 41·5 | 33·1 | W | 26 | 28·867 | 28·925 | 29·048 | 29·147 | 40·3 | 32·9 | WNW |
| 27 | 29·422 | 29·541 | 29·596 | 29·657 | 39·1 | 27·0 | SW | 27 | 29·220 | 29·334 | 29·370 | 29·404 | 38·7 | 33·8 | WSW |
| 28 | 29·607 | 29·501 | 29·280 | 29·077 | 48·1 | 27·5 | S | 28 | 29·336 | 29·194 | 29·020 | 28·960 | 38·2 | 33·0 | E |
| 29 | 29·110 | 29·295 | 29·361 | 29·545 | 47·0 | 40·4 | SW | 29 | 28·950 | 29·023 | 29·146 | 29·270 | 41·0 | 34·4 | W |
| 30 | 29·576 | 29·595 | 29·663 | 29·705 | 54·6 | 41·1 | SW | 30 | 29·222 | 29·080 | 29·042 | 29·116 | 49·1 | 38·1 | SW |
| 31 | 29·856 | 29·939 | 29·897 | 29·799 | 53·3 | 51·2 | SW | 31 | 29·226 | 29·438 | 29·539 | 29·513 | 48·9 | 42·6 | WSW |

# INDEX TO VOL. XXIII.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname; or, in the case of the name of any Firm, Association or Institution, the full name of such Firm, etc.

Discussions are printed in *italics*.

The following contractions are used :—

M.—Midland Institute of Mining, Civil and Mechanical Engineers.

M.C.—The Midland Counties Institution of Engineers.

S. Mining Institute of Scotland.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.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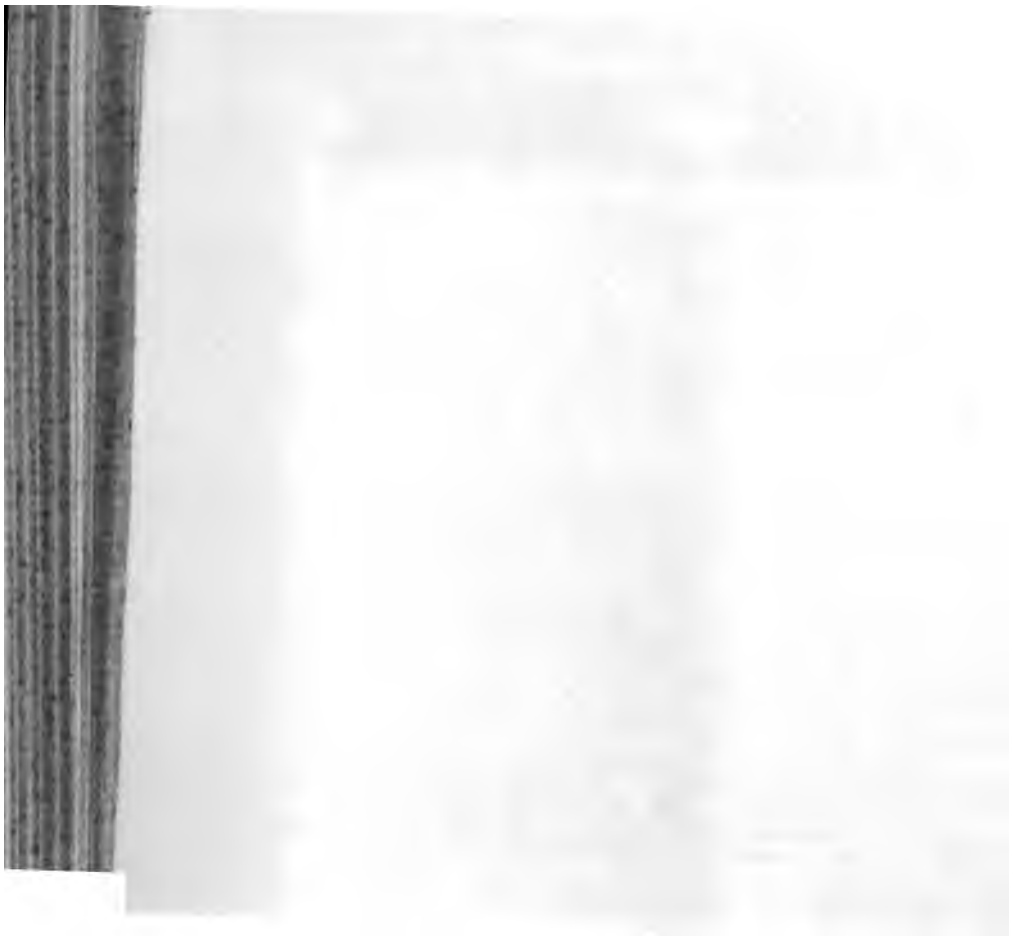

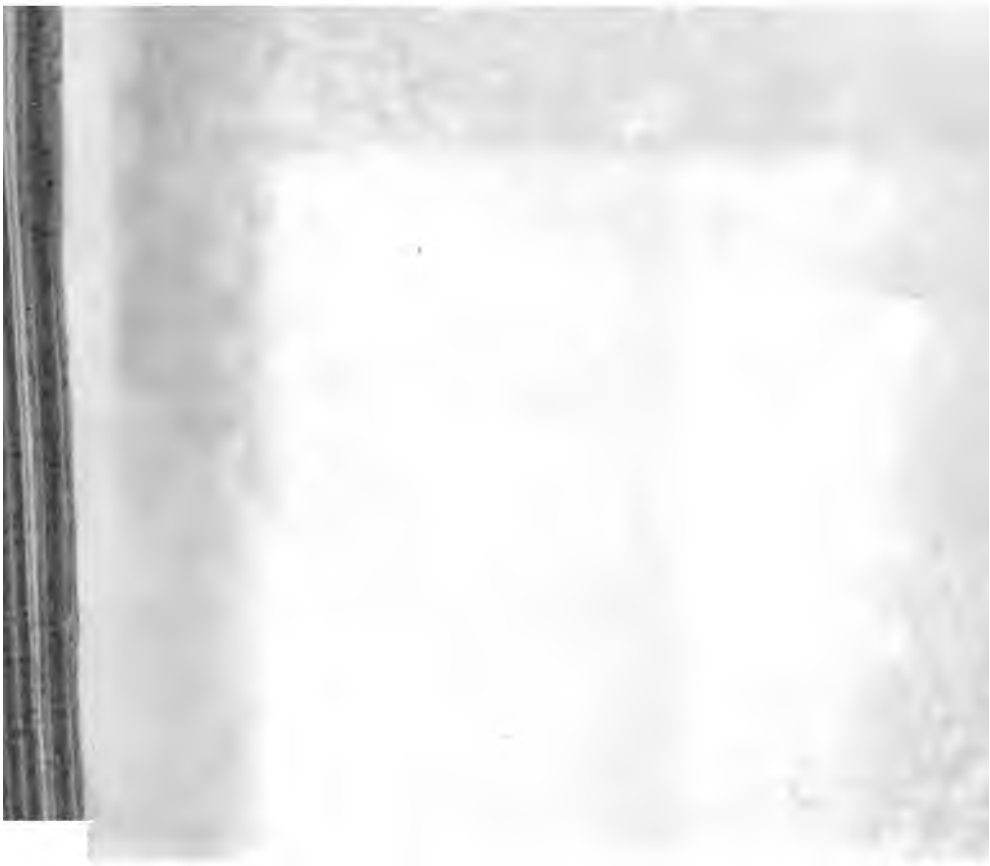

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